ILLINOIS
State Geological Survey

BULLETIN NO. 3.

Composition and Character of Illinois Coals,
By S. W. PARR,

With Chapters on the
Distribution of the Coal Beds of the State,
By A. BEMENT,

AND

Tests of Illinois Coals Under Steam Boilers,
By L. P. BRECKENRIDGE.

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STATE GEOLOGICAL SURVEY,
UNIVERSITY OF ILLINOIS,
URBANA, JULY 1, 1906.

Governor C. S. DENEEN, *Chairman, and Members of the Geological Commission.*

GENTLEMEN—I submit herewith a report upon the composition and character of Illinois coals by Professor S. W. Parr, of the State University, consulting chemist of the Survey, and respectfully recommend its publication as a bulletin of the Survey. With Professor Parr's report are chapters upon the distribution of the coal beds of Illinois by Mr. A. Bement, consulting engineer, and on tests with Illinois coals under steam boilers by Professor L. P. Breckenridge, of the State University and the Engineering Experiment Station. The whole of this report is in a large sense preliminary and the results here given are to be considered essentially tentative. It constitutes a summary of the best information now available. The Survey has been in operation for such a short time that it would be quite impossible to present any such report on the basis of its own investigations. There have, however, been so many and such insistent calls for information regarding Illinois coals that it was thought wise to prepare this report for immediate use. The Survey is under great obligations to Professors Parr and Breckenridge and to the University for permitting the use of material already accumulated. These portions of the report should be considered the results of co-operation between the Survey, the Engineering Experiment Station and the Department of Applied Chemistry of the University.

Professor Parr's studies of Illinois coals began several years ago. Preliminary statements of results have been published in bulletins of the bureau of labor statistics* and of the University.† In the

* Chemical analysis and heating value of Illinois coals, by S. W. Parr, Bull., Bureau of Labor Statistics. David Ross, Secretary, Twentieth Ann. coal report, 17 pages, 1902.

† The coals of Illinois; their composition and analyses, by S. W. Parr, University of Illinois, bulletin, Vol. I., No. 20, 40 pages, 1904.

former were given the results of 260 proximate analyses of samples variously collected. In the second the results were based upon 150 car samples collected mainly by the State Mine Inspectors. The samples in the latter case were shipped in canvas bags, and there is accordingly no means of determining the original moisture content. The results are not altogether satisfactory and steps have already been taken to collect a new set of samples upon which future investigations may be made. In the meantime to determine exactly what investigations should be taken up and what methods should be followed, the old samples have been re-investigated. Much more information is needed regarding the real nature of coal and the state of combination of its elements. Professor Parr's earlier results had shown that coals of the same composition, as measured by ultimate and proximate analyses, might differ greatly in character and adaptability because of the different sorts of bond existing between the carbon, hydrogen and other elements, . It is important to know what these combinations are and to devise a ready method of determining them. The old samples were therefore partially reanalyzed and a considerable number of additional determinations made. A new classification of coals has been developed which is believed to represent a distinct advance. In the present bulletin this classification is applied to a large number of existing analyses. It is believed that the method here worked out will prove useful in directing attention to certain little understood elements of coal, and that with a more complete understanding of the material it will prove possible not only to burn it with greater economy but also to adapt various grades to coke making, gas producing and other uses from which they are now shut out.

The coal fields of Illinois constitute the State's most important mineral resource. Extending as they do for 275 miles in a north-south direction, and 225 miles from east to west, they include approximately 42,900 square miles, a larger area than is included in the coal fields of any other American state. They constitute a part, albeit the largest part, of the eastern interior coal field, which occupies a great shallow structural basin in Illinois, southwestern Indiana and western Kentucky. The rocks belong to the Coal Measures of the Carboniferous, and are separable into three division: (a) Upper or Barren Coal Measures; (b) Lower or Productive Coal Measures; (c) The Millstone grit or Lansfield sandstone. On the accompanying map, plate 1, the Upper and Lower Coal Measures are shown; the Mansfield sandstone being mapped with the latter. Near Danville there is a limited area of Permian beds, but this is not discriminated on the map. The productive beds

are found in the Lower Coal Measures but are extensively mined within the area of outcrop of the upper measures by sinking through the latter.

In the reports of the older Geological Survey, 16 coal beds were recognized, of which beds 1 to 7 are commonly worked. The developments of recent years have raised certain questions regarding the accuracy of this general section and the correlation of particular beds. It will be the work of the present Survey to determine as correctly as possible the true position and extent of each bed. To serve present purposes the map constituting plate 3 is presented. On this map is shown the distribution of the various coal beds as determined by Mr. A. Bement. In the accompanying paper Mr. Bement explains the data upon which the map is constructed. As he states, the numbers as now used are essentially local names and very little reliance can be placed upon the supposed correlations between districts. Mr. Bement rather than the Survey is responsible for this presentation of the subject. We are under great obligation to him for preparing it as well as for a lively interest in the whole investigation and many helpful suggestions.

Not only is the coal field of Illinois the most extensive in any of the states but it was the first to attract attention, and its development of recent years has been remarkable. Mr. E. W. Parker* summarizes the history of the field as follows:

"Probably the earliest mention of coal in the United States is contained in the journal of Father Hennepin, a French Missionary, who, as early as 1679 reported a 'cole' mine on the Illinois river above Fort Crevecoeur, near the site of the present city of Ottawa. Father Hennepin marked the location of the occurrence on the map which illustrates his journal. It is probable that outside of anthracite mining in Pennsylvania and the operations in the Richmond basin of Virginia, Illinois holds the record of priority in production. The earliest statement we have in regard to actual mining in Illinois, is that coal was produced in Jackson county in 1810 from a point on the Big Muddy river. A flatboat was loaded with coal at this place and shipped to New Orleans, but the amount was not stated. Again it is reported that in 1832 several boat loads were sent from the same vicinity to the same market. Another record is found stating that 150,000 bushels (or 6,000 tons) of coal were mined in 1833 in St. Clair county and hauled by wagons to St. Louis. From 1840 to 1860 the bureau of statistics of the State is without any reliable data in regard to the coal mining industry, although some scattering statistics are found in the geological reports published by the government.

* U. S. Geol. Survey, Mineral Resources of the United States, 1904, pp. 471-472.

The table following shows the statistics of coal production in Illinois from 1833 to 1904, inclusive, and for the years for which there is no special information the production has been estimated by the writer."

Coal production of Illinois, 1833-1904.

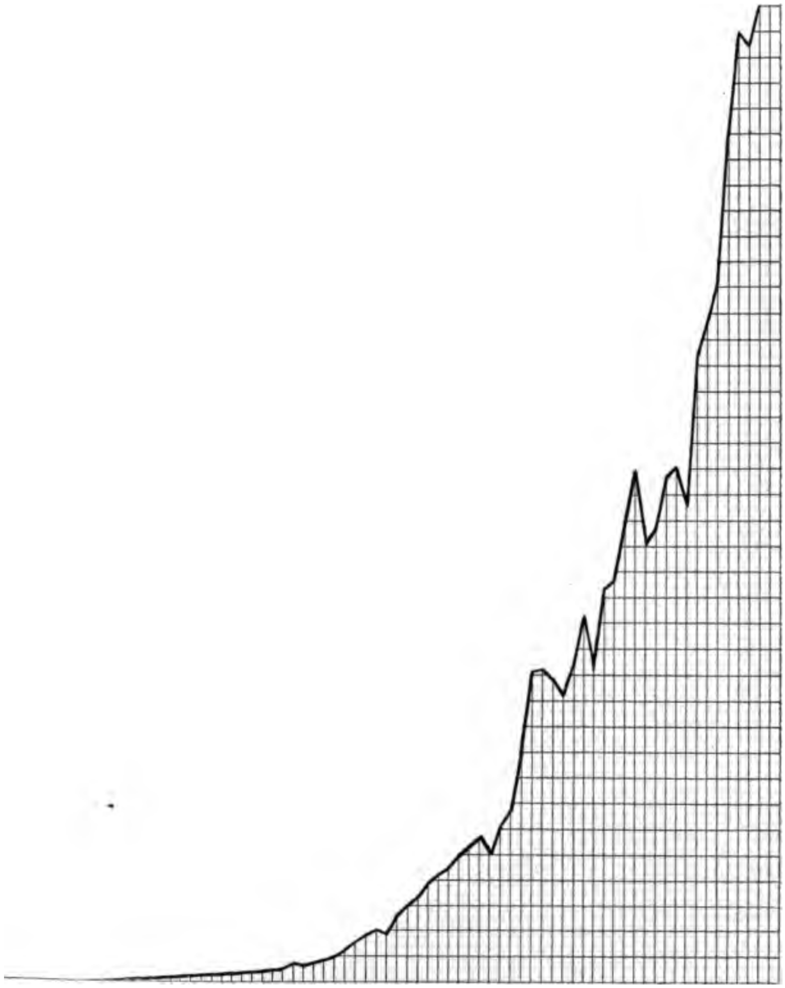
(Short tons.)

Year.	Quantity.	Year.	Quantity.
1833	6,000	1869	1,854,000
1834	7,500	1870a	2,624,163
1835	8,000	1871	3,000,000
1836	10,000	1872	3,360,000
1837	12,500	1873	3,920,000
1838	14,000	1874	4,203,000
1839	15,038	1875	4,453,178
1840a	16,967	1876	5,000,000
1841	35,000	1877	5,350,000
1842	58,000	1878	5,700,000
1843	75,000	1879	5,000,000
1844	120,000	1880	6,115,377
1845	150 000	1881	6,720,000
1846	165,000	1882	9,114.653
1847	180 000	1883	12,123,456
1848	200,000	1884	12,208,075
1849	260,000	1885	11,824,459
1850	300,000	1886	11,175,341
1851	320,000	1887	15,423,066
1852	340,000	1888	14,328,181
1853	375,000	1889	12,104,272
1854	385,000	1890	15,292,420
1855	400,000	1891	14,660,698
1856	410,000	1892	17,862,296
1857	450,000	1893	19,949,564
1858	490,000	1894	17,113,576
1859	530,000	1895	17,735,864
1860a	728,400	1896	19,786,626
1861	670,000	1897	20,072,758
1862	780,000	1898	18,599,299
1863	890,000	1899	24,439,019
1864	1,000,000	1900	25,767,981
1865	1,260,000	1901	27,331,552
1866	1,580,000	1902	32,939,373
1867	1,800,000	1903	36,957,104
1868	2,000,000	1904	36,475,060

a United States Census, fiscal year.

The growth in production is shown graphically in figure 1, based upon the data of the preceding table to which is added the production of 1905. The detailed figures for the latter year are given below. These figures for the calendar year are from statistics collected by Mr. Frank Van Horn, of this Survey, in co-operation with the U.

S. Geological Survey. For the sake of comparison the production for the fiscal year ending June 30, 1905. is also given. The figures were collected by the Bureau of Labor Statistics and are published through the courtesy of Mr. David Ross, Secretary.



FIF. 1—Growth of coal production in Illinois 1833-1905. Horizontal spaces represent years; vertical spaces, million tons.

Coal Production of Illinois in 1905.

Counties.	Fiscal Year Ending June 30, 1905. Tonnage.	Calendar Year 1905. Tonnage.	Calendar Year 1905. Value.	Number of producers reporting.
Bond	129,815			1
Brown	1,606			
Bureau	1,751,875	1,699,268	$2,416,807 00	17
Calhoun				1
Cass	2,590			
Christian	857,890	879,360	970,852 00	8
Clinton	904,826	579,281	516,268 00	7
Edgar	5,550			
Franklin	136,788	225,980	222,829 00	3
Fulton	1,439,489	1,519,049	1,760,246 00	26
Gallatin	76,629	77,010	76,473 00	5
Greene	14,659			2
Grundy	1,326,109	1,311,542	2,097,952 00	23
Hamilton	200			
Hancock				1
Henry	159,019	147,095	231,230 00	18
Jackson	802,101	818,841	1,004,875 00	14
Jefferson				1
Jersey	3,141			
Johnson	2,400			
Kankakee	700			
Knox	68,981	60,330	70,904 00	20
LaSalle	1,696,853	1,780,438	2,685,098 00	27
Livingston	244,394	272,418	378,783 00	8
Logan	384,288	445,546	470,523 00	4
Macon	196,628	231,235	359,228 00	5
Macoupin	2,530,840	3,214,473	2,982,855 00	20
Madison	2,987,906	3,179,162	2,748,035 00	30
Marion	1,086 330	1,009,759	906,656 00	6
Marshall	510,968	499,672	703,607 00	6
McDonough	43,944	22,299	36,961 00	8
McLean	175,010	159,921	246,552 00	3
Menard	448,433	415,266	414,490 00	13
Mercer	544,220	532,854	687,539 00	13
Montgomery	468,198	598,064	571,522 00	6
Morgan				2
Peoria	904,892	825,264	942,130 00	40
Perry	1,268,718	1,385,291	1,241,685 00	28
Putnam	42,964			
Randolph	506,547	439,623	396,631 00	10
Rock Island	78,784	53,582	94,110 00	8
Saline	427,262	281,461	268,083 00	7
Sangamon	4,395,050	4,696,363	4,306,002 00	36
Schuyler	21,470	3,355	5,933 00	3
Scott	14,876	13,423	24,195 00	3
Shelby	121,212	104,216	173,639 00	8
Stark	38,431	19,013	33,745 00	8
St. Clair	3,398,032	3,611,161	3,022,569 00	78
Tazewell	235,001	225,573	256,546 00	11
Vermilion	2,618,375	2,291,266	2,205,622 00	46
Warren	17,486	9,330	19,253 00	3
Washington				2
White	1,000			
Will	128,751	137,957	236,256 00	4
Williamson	3,815,751	3,927,910	3,529,968 00	35
Woodford				2
Bond, Calhoun, Greene, Hancock, Jefferson, Morgan, Washington, Woodford	390,846	377,323	437,412 00	
Totals	37,183,374	38,081,574	$39,754,071 00	630

The present intensity of production in the various counties is shown graphically in plate 2, which is based on the figures for the fiscal year given above. As indicated by the table the map would be changed slightly if the figures for the calander year were substituted. These tables indicate something of the growing importance of the Illinois coal fields. In the last twenty-five years the production of the State has increased 519 per cent. If the same rate of increase continues for another quarter of a century the annual production will then be approximately 135,000,000 short tons. The production for the last ten years has increased at even a more rapid rate, amounting indeed to 113 per cent. At this rate a production of 80,000,000 tons will be reached in ten years, and approximately 280,000,000 tons in twenty-five years. This is about the amount of bituminous coal now mined and sold in the whole of the United States. It is impossible to say what the future rate of increase will in fact be, but these figures are at least serious possibilities, and the production will undoubtedly very rapidly increase for many years to come.

While the coal reserves of the State are large, so large in fact that no estimate of value can yet be made, they are not inexhaustible. It is true that there are many square miles wholly untouched, and that few of the present mines work to anything like the capacity of the plant. It is none the less sound policy to look forward to the time when the coal reserves will be much less extensive, and even to that far time when they will be exhausted. To make the best uses of our resources it is necessary to study, and to improve where possible, the methods of finding and mining the coal and of using it. The former involves careful studies of the coal in the ground; of the stratigrophy of the coal field, the relations of the various coal beds, the roof and floor clay, the contained gases, the underground water, the various faults, and indeed everything involved in the geology of the field and the mode of occurrence of the beds. To this end the Survey has taken up (a) a study of the general geology of the coal fields, (b) detailed Surveys designed to make out the distribution of the individual coal beds, to locate the faults and other structural features, and to furnish adequate maps for the economical development of the area.

Improvement in the utilization of the coal is not less important than more knowledge for locating it. Too much coal is left in the ground and too little benefit is derived from that which is burned. It is proposed therefore to carry on studies designed to furnish data regarding gas in the coal, the character of roof, of the floor, and similar natural phenomena which condition the methods of working, with the hope that the actual mining methods may be somewhat improved.

In connection with the Engineering Experiment Station it is further proposed to carry on boiler and other tests in order to learn the best method of burning or otherwise using each size and market grade of coal. This work will be under the direction of Director L. P. Breckenridge of the Experiment Station, but toward it the Survey contributes by selecting and sampling the coal to be tested as well as by studying the field relations.

A large number of boiler trials have already been made of Illinois coal. Those which were available were summarized by Professor Breckenridge, and are presented in the accompanying tables. It is fully recognized that many variables enter into such a table and much additional work needs to be done. In particular it is planned to make tests of washed and unwashed coal from the same mine; of the same coal in different sizes, and to carry on various other lines of research. A single boiler trial, like a single analysis, does not mean much, but a series of systematic tests should yield information of the highest import.

A very large portion of Illinois coal is marketed within the State; the remainder is shipped mainly to the north and west. Despite its abundance and low price Illinois coal does not command the entire market, even within the limits of the State. For example, in January and February, 1906, according to the Chicago Bureau of Coal Statistics, 2,226,596 tons of bituminous coal were shipped into the city, of 1,606,338 tons were used there, and 620,258 tons re-shipped. The coal came from Illinois, Indiana, Ohio, Pennsylvania and West Virginia. Illinois contributed approximately 52 per cent, Indiana 27 per cent, and the remaining states 21 per cent. Coal from the eastern states is sold here partly upon the basis of quality and partly by reason of favorable freight rates and low mining costs. It will probably never be possible, and it would be undesirable, to entirely eliminate the movement of coal from the east into the State and across the State into the territory where Illinois coals largely dominate the market. It should be possible, however, to materially reduce the amount of these shipments, and in particular to see that a much larger portion of the increasing trade is supplied from Illinois mines. To do this requires much closer attention to be paid to the methods of mining and marketing the coal, particularly as regards its sizing, screening and washing. Careful studies should also be made of the demands of different industries and territories, and of the movement of coal. Just how far it may prove possible for the Geological Survey to go into this subject is uncertain, but it is believed that there is a wide field of usefulness for such studies. Certain, at least, of the

topics should be investigated. There is a strong demand in the middle west for a coal capable of producing a metallurgical coke. It is not impossible that certain of the Illinois coals may prove to be valuable for this purpose, either when coked alone or mixed with coking coals. The great importance of such a find warrants, it is believed, some investigation.

The first step in this as in the other lines of work outlined is obviously a complete knowledge of the character of the coal in the ground. Accordingly the mines of the State are now being visited by Messrs. J. J. Rutledge, Tom Moses and F. F. Grout, for the purpose of noting the thickness and character of the beds and of obtaining a systematic set of samples of the coal taken according to carefully determined rules. This work is still in progress. The new samples are to be the basis of the further study of the composition and character of Illinois coal supplementary to the present bulletin. This is, as already stated, to be regarded as preliminary, and is only designed to answer the needs of the State until these newer and fuller investigations are completed. Trusting that from this point of view the present report may be acceptable, I am,

Very respectfully yours,

H. FOSTER BAIN,

Director.

DISTRIBUTION OF THE COAL BEDS OF THE STATE.

(By A. Bement.)

It is the writer's particular wish to emphasize here the need of certain lines of work of great commercial value to the people of Illinois, rather than to attempt the presentation of any facts or theories regarding the Illinois coal field. For this reason an explanation of the map showing the areas of the State underlain by various coal seams and published here for the first time, will be given with the writer's reason for his conclusions, and the authority upon which these conclusions are based.

The numbers used to designate the various coal seams are those originated by Professor Worthen in the first Survey, perpetuated by the State Mine Inspection Department and frequently published in the annual coal reports. With one exception these numbers have been employed without question in the preparation of this map. This exception is in the case of the seam extensively mined in the southern part of Sangamon, certain portions of Macoupin and Christian counties, and usually referred to as No. 5. This the writer would designate as No. 6, since the No. 5 seam, in Sangamon county, north from the mine of the Illinois Collieries Company at the town of Chatham, differs in physical characteristics from the No. 6, which is worked so extensively in all the counties to the south as far as the northern portion of Jackson county. In the latter territory this seam may readily be identified by certain persistent and regular horizontal bands of impurities, the most important of which is a band of "slate" known as the "blue band," approximately from three-fourths to one and one-half inches in thickness and located about two feet above the bottom of the seam. Other bands of pyrites are also persistent and regular. The No. 5 seam, on the other hand, is characterized by the presence of certain fissures extending vertically through the seam, filled with hard rock in those cases where the fissures or cracks are narrow, and with "clay" where they are wide. These

cracks or fissures, which sometimes extend for a considerable distance, are not continuous. They are usually referred to as "horse backs." The coal seam in these mines presents a black and apparently clean face, while the bands in the No. 6 seam are always apparent. Thus the impurities in the No. 6 seam may be referred to as being horizontal, while that in No. 5 is vertical, and the appearance of the face of the No. 5 coal suggests that its ash content is much lower than with the No. 6 seam. This, however, is not true, as the entire ash of the two seams is approximately the same, even when the horse backs are excluded from consideration. These two seams are often referred to as the "horse back" and "blue band" coals, and as the blue band coal in the greater portion of its important areas is referred to as No. 6, the writer considers that it should be so designated over the entire area.

The Illinois coal seams referred to by the numerical system have been designated in their supposed "geological" order, and the implication is, that the various horizons have been determined and correlated. This, however, is not the case, and it does not follow that the seam known as No. 5 in Sangamon and Saline counties occupies the same horizon. At the best the numbers cannot be regarded as more than local names when the State as a whole is considered, although the numerical system as now applied is consistent over quite extended local areas.

In the preparation of the map the writer has been guided by the state coal reports, has inspected many mines, and has used information afforded by a large number of borings. The beds as shown are those of greatest importance in the respective areas as far as now known, but it does not follow that future investigation will not justify somewhat different mapping. A considerable area has been shown as underlain by what is designated as unknown coal. This, as far as the center of the basin is concerned, might with some justification be regarded as containing seams Nos. 1 and 2, since there appears to be reason to believe that these two seams are present in moderate thickness over at least a greater part of the entire basin. As a working hypothesis it may be assumed that the coal beds lying above No. 2 in the western part of the state, are persistent in extent and thickness over large areas, and in the eastern portion that all of the seams are irregular in both extent and thickness. As a general rule, the quality of the coal becomes better with increasing depth, the lower seams being better than the upper ones. It also increases in value from north to south. Thus the No. 2 seam is better in the southern than in the northern portion of the State.

All of the important mining is in seams Nos. 1, 2, 5, 6 and 7. What are known as 3 and 4 are worked to only a very limited extent and produce coal for local use only. The relative importance of the different seams as far as tonnage output is concerned is as follows, No. 6 being the most important coal producer in Illinois:

No. 6,
No. 5,
No. 7,
No. 2,
No. 1.

Seam No. 1 is worked in three places in the State. The most important mining in it is in Mercer county, where four important mines have a comparatively large output. It and seam No. 2 which lies only a few feet above it at Assumption, Christian county, are operated by a shaft 1,008 feet deep, which is the deepest mine in the State. This seam is also worked to a small extent in Jackson county in the vicinity of Murphysboro.

Seam No. 2 is mined particularly in the northern part of the State, and nearly all the mining there is confined to it. It is known to a considerable extent as the Third Vein, a name originating many years ago at the city of LaSalle. In the majority of the mines it ranges in thickness from 3 to $3\frac{1}{2}$ feet and is worked by the long wall method. The cost of mining is high, but the coal is hard and strong, and for this reason ships well, commanding an important market where a long haul is necessary. It arrives in better condition than other and softer Illinois coal that could otherwise compete with it. Its market, however, is limited to fields demanding coal of this character.

There is also a small but very important bed of this coal in Jackson county at the town of Murphysboro, producing what is known as the Big Muddy coal of an excellent quality, considered to be the best mined in the State.

Seam No. 5 is operated extensively in Fulton and Peoria counties, but here it is not thick, averaging generally 4 feet, and for this reason cannot compete with thicker coal from other portions of the State on account of higher cost of mining. The principal output from the very large number of mines west of the Illinois river is from this seam, and shipment is very largely to Iowa and points outside of Illinois to the west. Around about Springfield and in Menard county, also extending north into Logan county, the No. 5 seam is thicker, averaging almost 6 feet. The roof is fairly good and mining conditions are favorable, so that there is a large output, especially at Springfield.

The seam known as No. 5 in Saline county is a very important one, and produces a coal of very high quality, equal to some of that from the upper seams in Ohio. This is a new field that has heretofore taken little part in production on account of lack of transportation facilities; the Cleveland, Cincinnati, Chicago & St. Louis Railway however, has improved its Cairo branch, so that now an excellent outlet is afforded. Mining conditions are very good in this locality, although the seam is irregular in thickness.

Seam No. 6 is the large producer of cheap coal; or, in other words, the seam which affords the greatest amount of heat for a given sum of money. It ranges in thickness from 6 to 8 feet in its known workable area, which is confined more particularly to the center of the Illinois coal field, although a small but very important field exists in Vermilion county south of Danville, where the bed is also known as the Grape Creek coal. In chemical composition this seam is not very different from the No. 5 in the center of the State, being a little higher in moisture. The average ash content of the two seams is about the same, but its distribution in No. 6 is different than in the No. 5. In the latter it is more evenly distributed throughout the seam, while in No. 6 there is less ash in that portion of the seam which produces the lump coal.

No. 7 seam is operated at three places in the State. In the past, the area around Streator, in LaSalle county shipped a very large annual tonnage from this seam.

The area over which it was present in important thickness, however, being limited, it is now almost worked out; for this reason the output has rapidly declined. This field was formerly one of the most important in the State, and supplied Chicago particularly with low priced coal before seams Nos. 5 and 6 were so extensively exploited. There is also an area of this coal to the west of Danville in Vermilion county, where there are a few mines which have an unimportant output. Its principal area, however, is in Williamson and Franklin counties, extending also a little way into Jackson and Perry counties. Fully one-half of Williamson county is underlain by this coal, and it is probable that it is below the surface at workable thickness in the greater part at least, if not all of Franklin county. As far as thickness and quality of coal are concerned, this is by all means the most important coal seam in the State, although other localities have transportation facilities and market outlets which give them an important advantage. This seam is the thickest in the State, running quite uniformly 9 feet over a greater part of the area, and generally ranging from 8 to 12 feet as far as known. A large portion of the fine coal is

washed and screened into various sizes and sold in this form, making a very superior fuel, about equal in ash content to the so-called Pocahontas and "smokeless" coals shipped into Illinois from the east, and affording some 25 to 30 per cent more heat for a given sum of money than obtainable from these eastern coals.

The importance of carefully discriminating the various coal beds lies in the fact that each bed has certain chemical and physical characteristics which determine the value of the coal and influence the methods of mining.

Coal may be considered as made up of three elements; pure coal, ash and moisture. Their relations are illustrated in the following equations:

1. $\left.\begin{array}{l}\text{Fixed carbon}\\ \text{Hydrocarbons}\\ \text{Sulphur}\end{array}\right\} + \left.\begin{array}{l}\text{Water of composition}\\ \text{Nitrogen}\end{array}\right\} = \text{Pure coal.}$
2. Pure coal + ash = dry coal.
3. Dry coal + moisture = moist coal.

If, as the writer believes, the pure coal in any particular seam or locality has a constant composition, it should be possible to determine it by a certain amount of careful work, after which the value could be used as a constant. The ash, however, is a decidedly variable factor and should have detailed attention. Lump coal from one mine may contain more ash than from another, not because of difference in the coal itself but by reason of the greater or less amount of ash associated with it. Moisture is the most variable of the three elements. In Illinois it usually decreases during shipment, so that the content of the seam is higher than of the coal as delivered to the consumer. The variable factors in the coal are largely controlled by the methods of mining, distance of transport and effect of weather in marketing, so that it becomes important to know the exact character of the coal in the ground and the extent of each seam in order to properly meet market conditions.

To a considerable extent confusion exists because of different and often erroneous methods of analysis or of statement of results. This matter has been discussed by the writer elsewhere* and Professor Parr's paper in this bulletin also takes it up. The importance of the matter warrants a few further words on the subject. Because of the great variability in moisture especially, it is absolutely necessary that all analytical data be presented on a common basis, illustrated in tables 1 and 2.

* Journal Amer. Chemical Society, vol. 28, p. 632.

TABLE 1.

Proximate Analysis.

	Moist coal.	Dry coal.	Pure coal.	Combustible.
Moisture	6.29	....	....	....
Ash	8.74	9.33	....	....
Total carbon	68.06	72.63	80.11	93.90
Fixed carbon	50.06	53.42	58.92	69.06
Volatile combustible	22.41	23.92	26.38	30.94
Water of composition	11.09	11.82	13.04	....
Available hydrogen	3.60	3.84	4.24	4.97
Volatile sulphur	0.82	0.87	0.96	1.13
Fixed sulphur	0.76	0.82	....	....
Total sulphur	1.58	1.69	0.96	1.13
Nitrogen	1.41	1.51	1.66	....
Total non-combustible	27.53	22.66	14.70	....
Total combustible	72.47	77.34	85.30	100.00
B. T. U. per pound	12,416	13,250	14,613	17,131

TABLE 2.

Proximate Analysis.

	Moist coal.	Dry coal.	Pure coal.	Combustible.
Moisture	9.91	....	....	....
Ash	11.51	12.78	....	....
Total carbon	63.55	70.54	80.87	94.73
Fixed carbon	48.42	53.75	61.62	72.20
Volatile combustible	18.65	20.70	23.73	27.80
Water of composition	10.28	11.40	13.08	....
Available hydrogen	3.03	3.36	3.85	4.51
Volatile sulphur	0.50	0.57	0.65	0.76
Fixed sulphur	0.70	0.78	....	....
Total sulphur	1.20	1.35	0.65	0.76
Nitrogen	1.23	1.37	1.57	....
Total non-combustible	32.93	25.55	14.65	....
Total combustible	67.07	74.45	85.35	100.00
B. T. U. per pound	11,348	12,596	14,442	16,921

The constituent here termed water of composition, is that proposed by Professor Parr, although the writer finds it necessary to obtain it from ultimate analysis. Table 3 presents a comparison of constituents of coals 1 and 2, arranged in parallel columns.

TABLE 3.

	COALS.	
	No. 1.	No. 2.
Combustible—		
Total carbon	93.90	94.73
Fixed carbon	69.06	72.20
Volatile combustible	30.94	27.80
Available hydrogen	4.97	4.51
Volatile sulphur	1.13	0.76
B. T. U	17,131	16,921
Pure coal—		
Water of composition	13.04	13.08
Nitrogen	1.66	1.57
Total non-combustible	14.70	14.65
B. T. U	14,613	14,442
Dry coal—		
Ash	9.33	12.78
Fixed sulphur	0.82	0.78
B. T. U	13,250	12,596
Moist coal—		
Moisture	6.29	9.91
B. T. U	12,416	11,348

Since determining the composition of coals 1 and 2 the writer has made experiments proving the uncertainty and unreliability of the volatilization method used to determine "volatile" and "fixed carbon" constituents, and has therefore abandoned this feature of analysis, adopting a form of proximate analysis shown in table 4. This is an analysis of a composite sample made up of other samples taken quite generally over one county. In the writer's opinion it can be used as a constant for the entire locality and seam, leaving only determinations of ash and moisture to be made in various sizes of coal shipped.

TABLE 4.

Proximate Analysis.

	Moist coal.	Dry coal.	Pure coal.	Combustible.
Moisture	13.76	....	....	....
Ash	....	12.25	....	....
Carbon	....	65.69	74.86	89.50
Available hydrogen	....	3.43	3.92	4.69
Sulpher, less S in ash	....	4.26	4.86	5.81
Nitrogen	....	1.08	1.23	....
Water of composition	....	13.29	15.13	....
Total combustible	....	73.38	83.64	100.00
Total non-combustible	....	26.62	16.36	....
B. T. U. per pound	10,751	12,467	14,208	16,987

COMPOSITION AND CHARACTER OF ILLINOIS COALS.

(BY S. W. PARR.)

COMPOSITION.

INTRODUCTION.

There are two sources of motion on the earth, chemical action and gravity. They are the initial forms of power and constitute the prime factors in industrial development. Their availability in any region is an index of present or potential activity. Of gravity it may almost be said that it has become a commodity by reason of its easy transformation into electric energy; but the supply in available form is localized and its range limited. Chemical energy in its cheapest form resides in the coal and oil deposits of the world. Their economical transformation is the great problem of the engineer. He has been largely occupied with boilers and grates and stokers, but recently a marked tendency is evident toward a more critical study of the fuel itself. As a contribution in that direction it is hoped that the accompanying study of the composition and properties of Illinois coal will not be without value.

Decomposition by decay.—Geologically coal is a mineral derived by process of decomposition from organic marterial consisting in the main of cellulose. We know the products of decomposition of this material when submerged to be oxides of carbon, (CO_2) and (CO), marsh gas, (CH_4), and water H_2O). These decompositions do not proceed regularly nor always to the same extent. For example, in the case of lignite, the breaking down of the vegetal structure has not gone so far as in the case of coal. The former may have lost 50 or 55 per cent. of its original substance, remaining light and of open

texture; the latter may have lost 65 or 70 per cent, becoming dense and compact. These varying degrees of transformation may be illustrated by the following chemical equations:

Vegetal tissue.		Loss by decomposition.				Coals.
(1) $5\,C_6H_{10}O_5$	=	$6\,CO_2$ + CO	+ $3\,CH_4$	+ $8\,H_2O$	+	$C_{20}H_{22}O_4$
Cellulose		Carbon oxides	Marsh gas	Water		Lignite
(2) $6\,C_6H_{10}O_5$	=	$8\,CO_2$ + CO	+ $5\,CH_4$	+ $10\,H_2O$	+	$C_{22}H_{20}O_3$
Cellulose	=	Carbon dioxide	Marsh gas	Water		Bituminous
(3) $7\,C_6H_{10}O_5$	=	$8\,CO_2$ +	$4\,CH_4$	+ $19\,H_2O$	+	$C_{30}H_{16}O$
Cellulose	=	Carbon dioxide	Marsh gas	Water		Semi-bituminous

From these equations we note that, assuming the original vegetal tissue to be in the form of cellulose, the products of decay are approximately the same in character, but vary in amount, while there remains a compound of indefinite chemical composition, yet which conforms in a degree to the hypothetical molecules as designated under the general heading of "coals."

We may further illustrate this transformation by the accompanying diagram, which also gives an idea of relative values involved in the transformation.

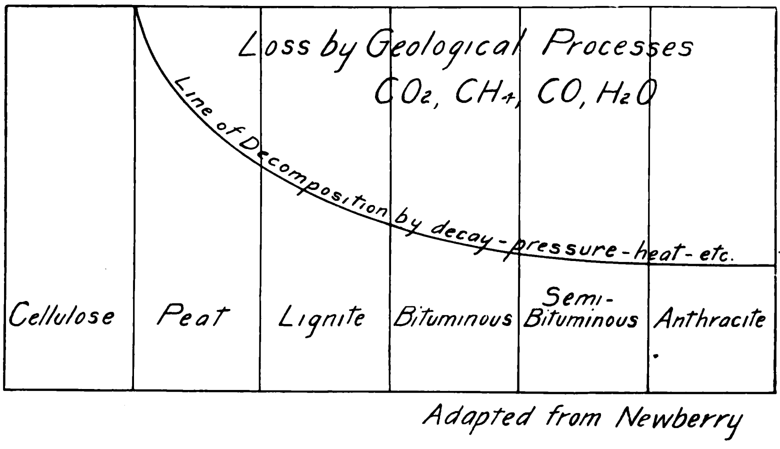


FIG. 2—Loss by decomposition in coal formation.

Decomposition by destructive distillation.—The routine through which vegetal matter has passed in arriving at the coal state may have in itself but little practical interest. No small amount of value, however, attaches to the information which may be thus developed concerning the properties, classification, etc., of the residual coal product. If we take these substances, for example, and subject them to high heat out of contact with the oxygen of the air, a new set of products will result. As in the case of decomposition by decay, so here

decomposition by destructive distillation may be illustrated by means of chemical equations. If, for example, we subject a piece of wood in a retort to a red heat, the decomposition will proceed approximately along the lines indicated as follows:

$2\,C_6H_{10}O_5$ =	$10C$	$C_2H_4O_2$	$8\,H_2O$
Cellulose	Charcoal	Pyroligneous acid	Water
100% =	37%	20%	43%

If we take the hypothetical coal molecules as developed by the equations in table 1, which are here considered as pure coal, i. e., ash and water free, and subject them to the same sort of decomposition by means of heat, we would have results of a somewhat similar nature and approximately as shown in table 2, thus:

TABLE 2.

	Coals.		Coke.		Volatile matter.		
(1)	$C_{20}H_{22}O_4$	=	$14C$	+	C_6H_{14}	+	$4\,H_2O$
	Lignite 100%		Fixed Carbons 51%		Hydrocarbons 26%		Water 23%
(2)	$C_{22}H_{20}O_3$	=	$16C$	+	C_6H_{14}	+	$3H_2O$
	Bituminous 100%		Fixed Carbon 58%		Hydrocarbons 26%		Water 16%
(3)	$C_{30}H_{16}O$	=	$26C$	+	$C_4H_{10}+4H$	+	H_2O
	Semi-bituminous 100%		Fixed Carbon 79.6%		Hydrocarbons 15.8%		Water 4.6%

These values may be also shown in their quantitive relations by a figure similar to that used to show the relative decomposition products due to decay as in figure 3, thus:

FIGURE 3.

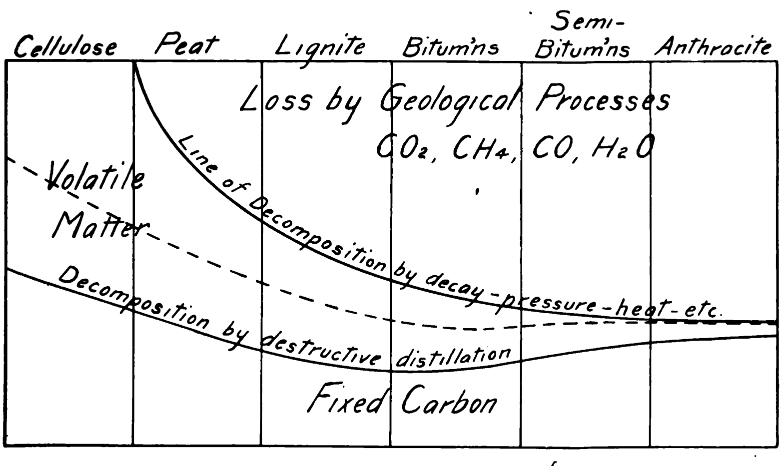


FIGURE 3—Loss by various geological processes in coal formation.

These various type products or coal molecules as developed in table 1 and figure 2, and further illustrated in table 2 and figure 3, have their counterparts in actual coal conditions, as shown by analysis. For example, the hypothetical molecules labeled "lignite," "bituminous coal" and "semi-bituminous coal," have these particular elements present in corresponding ratio in the various coals when the same are considered as exclusive of ash and water. By augmenting these molecules, therefore with ash and water in amounts corresponding to their respective types, this relation to percentages obtained from analysis of actual coal samples, may be shown as in table 3.

TABLE 3.

Description.	Pure Coal.			Extraneous material.	
	Fixed Carbon.	Volatile Matter.			
		Combustible.	Non-combustible.		
Lignite.					
Theoretical $C_{20}H_{22}O_4$ + Ash + Water =	14 C +	C_6H_{14} +	4 H_2O +	Ash +	Water
Percentages	42.4	21.6	19.1	2.7	14.0
Commercial Analysis of sample	41.3	20.3	21.6	2.7	14.0
Bituminous.					
Thoretical $C_{22}H_{20}O_3$ + Ash + Water =	16 C +	C_6H_{14} +	3 H_2O +	Ash +	Water
Percentages	49.3	22.0	13.6	8.0	7.0
Commercial Analysis of sample	49.4	21.6	14.0	8.0	7.0
Semi-Bituminous					
Theoretical $C_{30}H_{16}O$ + Ash + Water =	26 C +	4 H C_4H_{10} +	H_2O +	Ash +	Water
Percentages	76.1	15.1	4.3	3.5	0.9
Commercial Analysis of sample	76.8	14.5	4.2	3.5	0.9

An examination of this table shows that a close relationship exists between the suggested composition of the pure coal molecule and the actual composition as developed by analysis. The particular constituent that calls for further consideration, is the volatile matter.

VOLATILE MATTER.

In volatile matter it is evident that two distinct types of compounds exist; the one is composed of certain compounds of carbon and hydrogen, or hydrocarbons, which are combustible; the other, a compound of hydrogen and oxygen in the proper ratio to form water and hence non-combustible. It is manifestly inaccurate and misleading to apply to these products as a whole the term "volatile combustible." If the second of these constituents, the non-combustible part, were small in amount or constant as to quantity, it would perhaps not need special discussion. This condition indeed is approached in the semi-bitumiuous type of coal. The sample under this heading in table 3 is the well known Pocahontas variety. The composition as determined by proximate analysis, is as follows:

Analysis of Pocahontas Coal.

Ash	3.50%
Moisture	.92%
Volatile matter	18.70%
Fixed carbon	76.88%
Total	100.00%

Now if we analyze still further the volatile matter we shall find:

Combustible hydrocarbons	14.5 %
Non-combustible hydrogen, oxygen and nitrogen	4.2 %
Total	18.70%

It will be seen from this that over 22% of the volatile matter is non-combustible, but as this constitutes but 4.2% of the entire coal substance, it may be considered of small moment and only a minor error is involved in classifying the entire volatile matter as "combustible."

With the above, however, compare the composition of a coal of the bituminous type, also made use of in table 3 under the same heading:

Average of Ten Illinois Coals.

Ash	8.00%
Moisture	7.00%
Volatile matter	35.60%
Fixed carbon	49.40%
Total	100.00%

By further examination of the volatile matter we find:

Combustible hydrocarbons	21.6 %
Non-combustible hydrogen, oxygen and nitrogen	14.00%
Total	35.60%

Here it is evident that a much larger part of the volatile matter, equalling 14% of the entire coal, or 40% of the volatile matter itself is non-combustible.

The lignites also are of interest in this connection. A sample of the material from North Dakota upon analysis shows results as follows:

Lignite.

Ash	2.71%
Moisture	14.12%
Volatile matter	41.91%
Fixed carbon	41.26%
Total	100.00%
Combustible hydrocarbons	20.28%
Non-combustible hydrogen, oxygen and nitrogen	21.63%
Total	41.91%

It will be seen that 47% of the volatile matter or 21.63% of the entire coal included in the volatile matter, is non-combustible. In figure 3 this feature is illustrated, with a rather approximate indication of relative amounts, by the dotted line which divides the volatile matter into two parts; the non-combustible portion being above the line, and the combustible below. In order, however, to show more clearly the ratio of non-combustible to the total volatile matter, reference should be made to figures 4, 5 and 6. The same type samples are used with the percentage constituents as found by actual analysis.

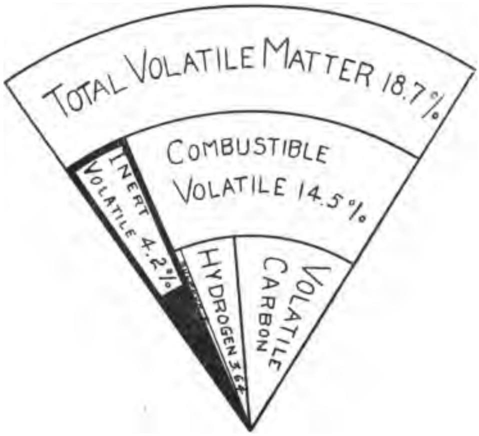


FIG. 4. Composition of volatile matter in semi-bituminous (Pocahontas) coal.

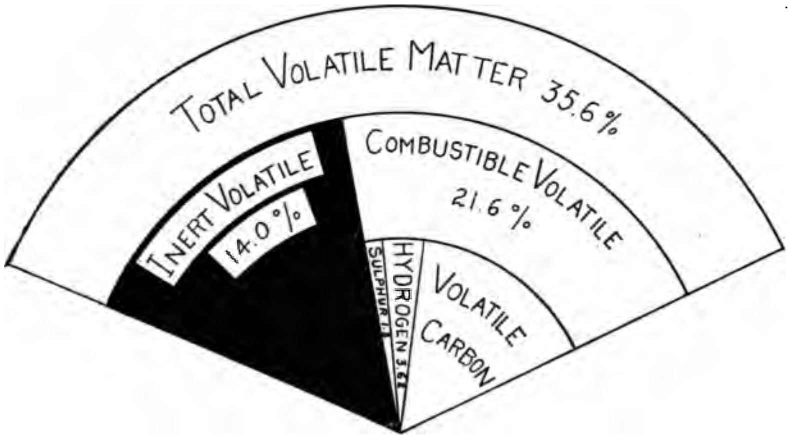


FIG. 5. Compositinn of volatile matter in Illinois coal.

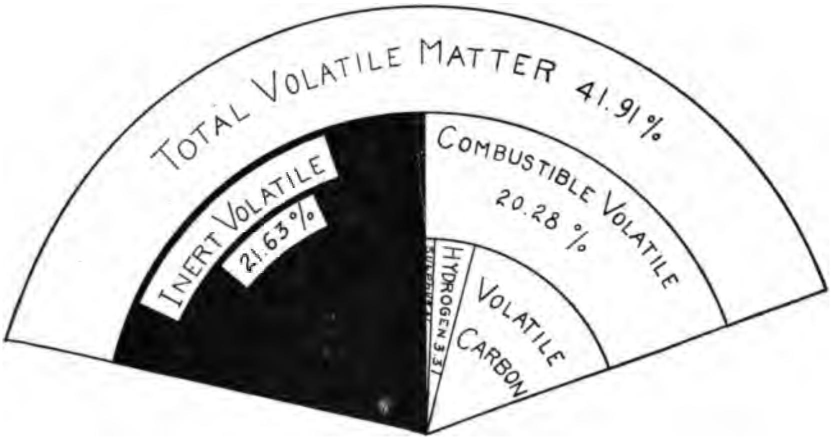
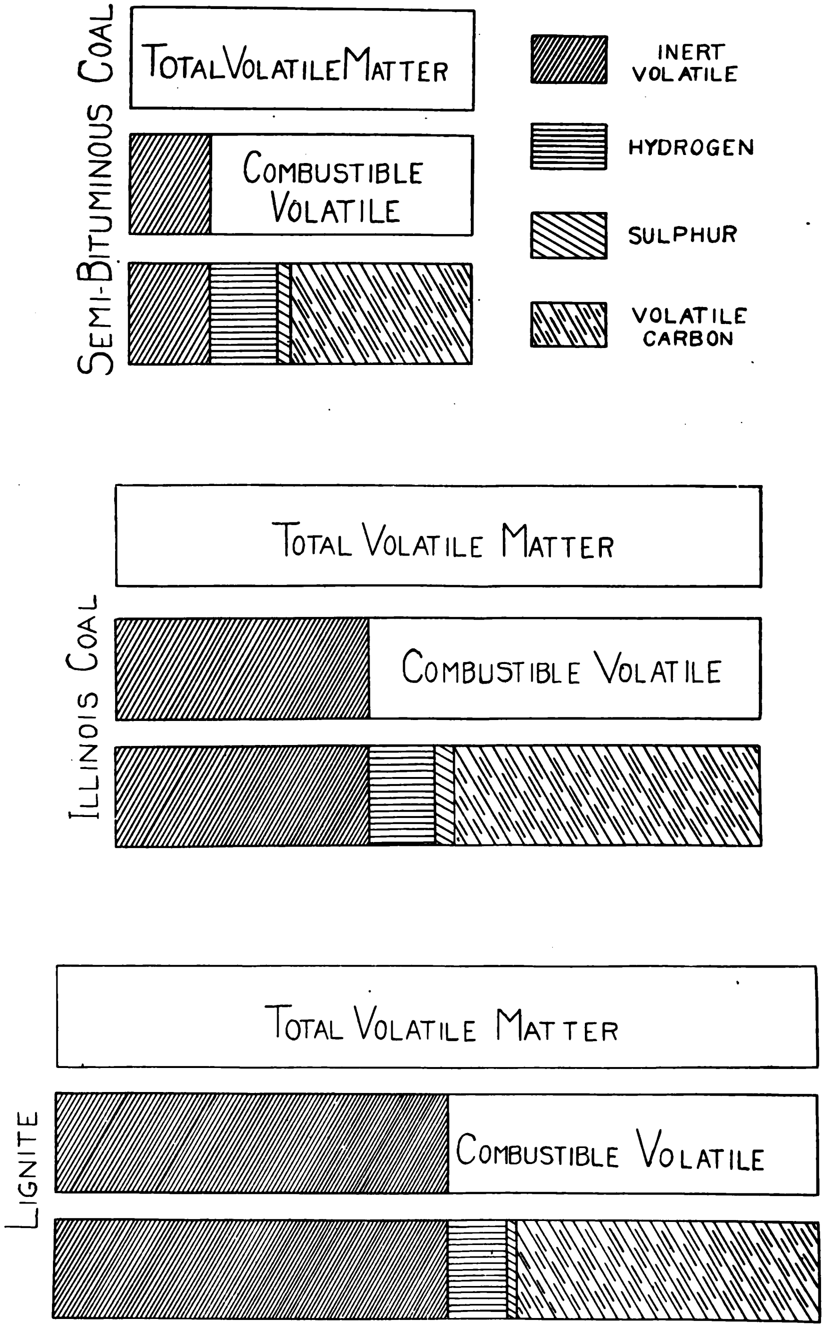


FIG. 6. Composition of volatile matter in lignite.



Comparison of the volatile matter in coals.

It should be especially noted that such a segment of a circle is taken as will represent the correct percentage part of the whole for the ordinary "volatile matter", exclusive of moisture, ash and fixed carbon. In plate 4 the same ratios are indicated by square areas.

The conditions illustrated suggest a number of queries. For example, what constitutes the proper fuel unit? It is not the coal as mined or delivered, because the content of moisture varies at every stage of transportation and handling. Moreover, both the moisture and the ash are to be looked upon as extraneous and incidental to the pure coal and not an integral part of it. They take no part in the combustion, hence the custom would seem to be erroneous of drawing the line of division here, and calling the ash and water the "non-combustible" and all the "ash and water free" portion the "combustible," and making use of this latter as the fuel unit. The error involved in the procedure is evident from the illustrations above given. In the case of Pocahontas coal, the difference is slight and the error small, and although over 22 per cent of the volatile matter is non-combustible, it constitutes only 4 per cent of the entire coal, hence the error resulting from this method of reckoning is not so great. By this method the engineer would calculate that 105 pounds of Pocahontas coal would make 100 pounds of combustible, i. e. as "ash and water free." In reality were the calculations based on the material present which actually burns, it would require 109.4 pounds to make 100 pounds of this true combustible. When we consider Illinois coal by these two methods of calculation, it would take 119 pounds to make 100 pounds of "combustible," considering that division as made on the usual "ash and water free" basis; whereas it would take, in fact, 141 pounds of coal to make 100 pounds of constituent that would actually burn. Here the error of basing the fuel unit on the "ash and water free" part is more evident. When we come to lignites the difference is still more striking. The common method of calculation would call for 120 pounds to yield 100 pounds of so-called "combustible"; whereas in fact, 162.5 pounds are needed for each pound of real combustible. By grouping these facts in a table the difference may be more readily compared.

TABLE 4.

Calculation of Fuel Units.

Kind of coal	Number of pounds of ordinary coal required to make 100 pounds of .... "Ash and water free" or so called "combustible," as commonly calculated.	True fuel: i. e. ash, water and non-combustible volatile free.	Error of common method in pounds of commercial coal per 100 lbs. actual combustible.
Pocahontas	104.62	109.43	4.81
Illinois	119.00	141.00	22.00
Lignite	120.23	162.49	42.26

Note from this table as indicated by the first column, that the steaming efficiency of a pound of lignite should be practically equivalent to a pound of Illinois coal, also that the handicap awarded Illinois coal in comparison with Pocahontas coal is less than one-fifth of what it should be. The true relations are properly indicated in the second column.

One other point may be worth mentioning in this connection. The gas engineer, for example, buys coal with an indicated analysis of 35 per cent of volatile matter. The yield of gas per pound when put to practical test is not so great as another lot showing only 19 per cent of volatile matter. He is aware that the condensation products such as tar, etc., are greater in the first case, but it is not conceivable that practically half of the volatile matter goes into tar. A little examination of figures 4 and 5 will offer a more rational explanation. It may be also suggested in this connection that by making a study of figures 5 and 6 in conjunction with table 3 in the matter of volatile matter of the combustible sort there is raised the question as to whether lignites might not enter the field as gas producers, at least in competition with coals of the bituminous type, especially when we consider the lower percentage of sulphur and condensation products.

It would seem desirable from consideration of what has preceded, that certain additional factors be introduced into our ordinary chemical results. This is not a simple matter, where methods have been long established, and especially where they have become the basis for calculations in other lines, as in steam engineering.

Two methods of procedure suggest themselves. First, we may obtain all our factors for coal by the methods of ultimate analysis. Such results would enable us to deduce the ratios used in illustrating

the errors already pointed out, and it may be fairly presumed that if such results had always been as easily available as those by proximate analysis, the former would have furnished the basis for establishing fuel units and all other data connected with coals. Indeed a large part of the argument in favor of retaining the method of proximate analysis, resides in the facility with which such results may be obtained as opposed to the greater elaboration and manipulative skill required for ultimate analysis. More than this the proximate analysis brings out certain indispensable factors such as the fixed carbon content, which would not appear if ultimate methods alone were used.

The second method of procedure to be suggested would be to add to the customary constituents as ascertained by proximate analysis, some further factor or factors reasonably convenient of determination, and which would also furnish the complete information desired.

These conditions seem to be met by adding the factor for the total carbon content. The chief argument in support of this position resides in the fact that it may serve directly in the determination of the available hydrogen, and having this factor, the percentage content of each of the three elements concerned in combustion would be at hand, viz., carbon hydrogen and sulphur.

AVAILABLE HYDROGEN.

By available hydrogen is meant that part of the hydrogen content which is free to enter into combustion with oxygen for the production of heat, as distinct from that hydrogen present which already has, as a constituent part of the molecule, the necessary equivalent of oxygen for the formation of water and consequently non-combustible and inert so far as heat producing properties are concerned. Given, therefore, the total carbon in addition to the usual constituents resulting from proximate analysis, the proposition before us is to deduce the available hydrogen.

If we examine the reactions in table No. 2, where the conditions correspond to those under which the proximate method is carried on involving destructive distillation, we note that the volatile hydrocarbons tend to conform to certain combinations for any given type of coal; indeed there seems to be a certain kind of uniform progression running throughout all the reactions, from the geological decomposition processes to the ultimate result of destructive distillation.

In table No. 2, for example. reaction (2) illustrates by chemical equation almost exactly the composition and decomposition products of a particular sample of Illinois coal. If we put into similar form

the results from a number of actual analyses, and include in the series the extremes of the Illinois type from those approaching the semi-bituminous to those bordering on the lignitic form, we shall have a series of reactions as below. To make more evident the progressive nature of the reactions, there are added two columns showing in each instance the ratio between the volatile carbon (v c) and the total carbon (C), and between the available hydrogen (H) and the volatile carbon (v c). By volatile carbon is here meant that part of the carbon which is joined with hydrogen to make some member of the hydrocarbon series as distinct from the fixed carbon, which is the chief constituent of the coke. The sum of these two forms of carbon of course equals the total carbon.

TABLE 5.

	Bituminous Coal.		Hydrocarbons.		Water.	$\frac{v\ c}{C}$	$\frac{H}{v\ c}$
(a)	$C_{18}H_{16}O_3$		$C_{15}+C_3H_8+_2H$	+	$3\ H_2O$	16.6%	28%
(b)	$C_{24}H_{18}O_3$	=	$C_{20}+C_4H_{10}+_2H$	+	$3\ H_2O$	20%	2[illegible]%
(c)	$C_{18}H_{18}O_3$		$C_{13}+C_5H_{12}$	+	$3\ H_2O$	27.7%	20%
(d)	$C_{22}H_{20}O_3$		$C_{16}+C_6H_{14}$	+	$3\ H_2O$	29.2%	19.4%
(e)	$C_{18}H_{22}O_3$		$C_{11}+C_7H_{16}$	+	$3\ H_2O$	39%	16.5%

These reactions are illustrative merely, but they have their counterparts in actual coal samples. The last two columns show in percentage form the carbon and hydrogen ratios. The ratios of volatile carbon to total carbon increase from 16.6% to 39%, while in a descending series the ratios of the available hydrogen to the volatile carbon vary from 28% to 16.5%. This suggests a curve in which the abscissae shall be $\frac{v\ c}{C}$ and the ordinates $\frac{H}{v\ c}$. Knowing therefore in any given case the factors for volatile carbon, there is indicated from these ratios and by means of such a curve, the percentage part the hydrogen is of volatile carbon. In the accompanying diagram (Fig. 7) curve No. 1 is drawn in accordance with the above type reactions of table 5.

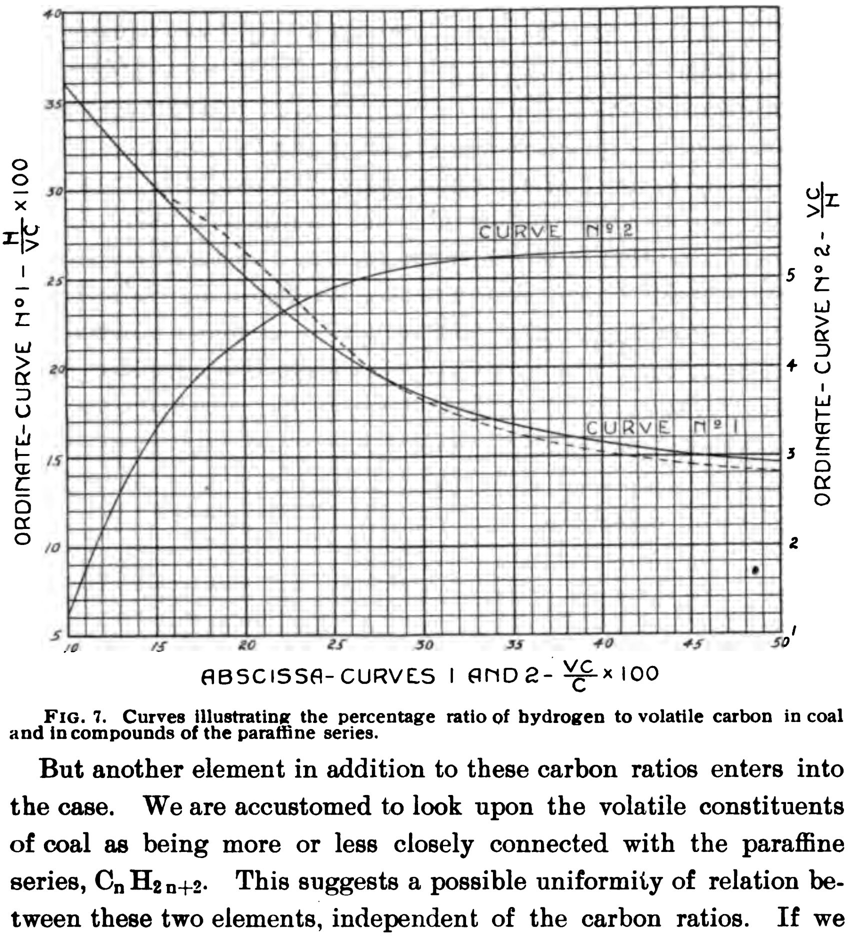


FIG. 7. Curves illustrating the percentage ratio of hydrogen to volatile carbon in coal and in compounds of the paraffine series.

But another element in addition to these carbon ratios enters into the case. We are accustomed to look upon the volatile constituents of coal as being more or less closely connected with the paraffine series, $C_n H_{2n+2}$. This suggests a possible uniformity of relation between these two elements, independent of the carbon ratios. If we tabulate a few members of this series we shall have results as follows:

In $C H_4$ the carbon is 3 times the hydrogen by weight.
In C_2H_6 the carbon is 4 times the hydrogen by weight.
In C_3H_8 the carbon is 4.5 times the hydrogen by weight.
In C_4H_{10} the carbon is 4.8 times the hydrogen by weight.
In C_5H_{12} the carbon is 5 times the hydrogen by weight.
In C_6H_{14} the carbon is 5.1 times the hydrogen by weight.
In C_7H_{16} the carbon is 5.2 times the hydrogen by weight.

Curve No. 2 in figure 7 is the expression of this series of compounds. It is located with respect to the carbon ratios, $\frac{vc}{C}$, in this manner: The last reaction (2) of table 5 shows the corresponding compound C_7H_{16}., but by the conditions of the equation the volatile carbon in C_7H_{15} is 39.2% of the total carbon, C_{18}, hence that point

where the ratio of $\frac{vc}{C}$ is 39.2% should be designated as the ordinate of $\frac{vc}{C}$ or 5.25; $(5.25+16=C_7$ or $84)$. Similarly from equation (d) C_6H_{14} shows $\frac{vc}{C}=5.14$, and this ordinate should be located at the point where $\frac{vc}{C}=29.2$ and so on to the first equation (a) where $\frac{vc}{H}=3.6$ and $\frac{vc}{C}=16.6$, thus locating the multiples 3.6:, 5.14, 5.25, etc., respectively at the carbon ratios, 16.6, 29.2 and 39.2. The chief modification ascribable to this series, as expressed by curve No. 2, is due to the fact that in the higher ratios the increase grows less and less, the volatile carbon never reaching six times the hydrogen; the curve therefore approaching continually the horizontal. In the lower members the rise which naturally is abrupt is accentuated by the tendency of the molecule to break down, yielding free hydrogen. This introduces a slight variable toward the extremes of curve 1, raising slightly its value at the upper end and depressing it at the right, as shown by the dotted line.

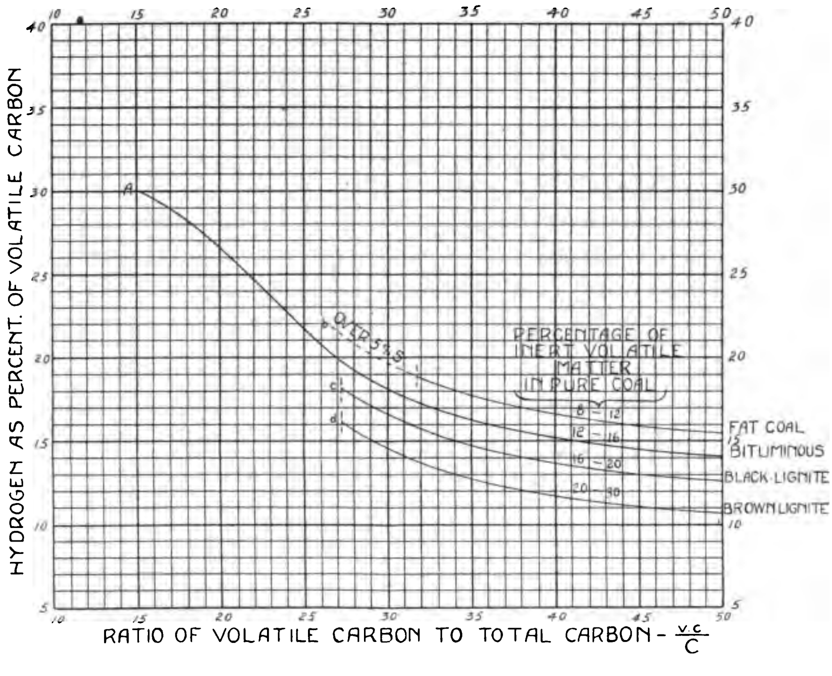


FIG. 8. Curve for calculating available hydrogen in coal.

For convenience in use, therefore, these two curves are combined into one resultant as shown in figure 8. Any such curve must of *necessity* be largely empirical, but the above illustration of some

of the methods which have entered into its development may offer a partial justification for its form.

It will be seen, therefore, that by having the total carbon factor in connection with the usual results from proximate analysis, we have $vc = C - fc$ (total carbon minus fixed carbon), and from this we develop the ratio of $\frac{vc}{C}$. The curve index of $\frac{vc}{C} \times vc =$ "H". An illustration of the use of the curve is as follows: In the following table Alabama coal No. 1 shows $fc = 53.71$: $C = 72.16$; hence $vc = 18.45$ and $\frac{vc}{C} = \frac{18.45}{72.16} = 25.56$. By reference to figure 8 this reading of the abscissa indicates on the curve that 21.3% of $vc = H$, i. e., $.213 \times 18.45 = 3.93$ or the percent of the available hydrogen in the coal.

Slight deviations from the curve, which refers to bituminous coals proper, are met with in the case of lignites and coals of the cannel type. These are provided for in the subsidiary curve b, c and d. Their use is illustrated under the topic "Variations from the Bituminous Type."

VARIATIONS FROM THE BITUMINOUS TYPE.

For indicating variations from the true bituminous type, the inert volatile matter is an all important factor. It is better if it be brought as near as possible to the oxygen-hydrogen basis and referred to the ash and water-free or pure coal condition. This is accomplished, as already indicated, by subtracting from 100% the sum of the total carbon, available hydrogen, ash, water and sulphur, and dividing this by 100%, minus the ash and water. The result shows a striking uniformity in that the percentage of combined water from this type of coal falls almost entirely within the range of from 11 to 16% of the pure coal. These variations, however, are to be noted. As we approach the lignitic end, where the ratio of volatile carbon to total carbon exceeds 27%, we may find an accompanying ratio of inert volatile exceeding 16%. If it falls between 16 and 20%, or between 20 and 30%, we are dealing with lignites proper and shall need to correct our factor for available hydrogen by reading from the subsidiary curve "d," figure 8, if the ratio of combined water exceeds 20%, and from the curve "c" if between 16 and 20%. This is in accord with the equations already used for illustration (Table 5) and agrees with the well-known fact that as the oxygen content of lignites increases, the factor for available hydrogen decreases.

Another deviation from the true bituminous type is met with which has opposite characteristics. These are of the cannel type and have

a carbon ratio in excess of 32%, but a combined water ratio of from 8 to 11%. These should have a corresponding increase in their index factor, and this is indicated in figure 8 by the curve marked "b." These variations have entered into the computations for the table.

In the subjoined table, fairly representative types of coal have been taken for illustrating the adaptability of the above method for indicating the available hydrogen from proximate results where the total carbon is also included as one of the factors. In this table the method for finding the hydrogen by means of the curve, as in the first hydrogen column, has been indicated above, page 41. In the next column, the hydrogen from ultimate analysis equals the total hydrogen—$\frac{O}{8}$. The column for hydrogen calcultated from indicated calories is found thus:

$$\frac{\text{Indicated Calories}-(8080\,C+2250\,S)}{34460}=H.$$

To test the adaptability of the curve the results from the St. Louis Testing Plant, and also by Lord and Haas,* have been added, and also the data on coals as published in the last Report of the Michigan Geological Survey, Vol. VIII.

TABLE VI.

PART I.

From Report of Coal Testing Plant, St. Louis, 1904†.

	Description.	Total carbon C.....	Volatile carbon vc...	Ratio $\frac{vc.}{C.}$	Reading from curve.	Hydrogen Values.		
						Hydrogen from curve.........	H. from ultimate analysis.	H. from indicated calories
1.	Alabama, No. 1	72.16	18.45	25.56	21.1	3.90	3.98	3.92
2.	Alabama, No. 2	69.24	17.50	25.27	21.6	3.78	3.43	3.77
3.	Arkansas, No. 1	75.68	7.56	10.00	45.0	3.40	3.42	3.79
4.	Arkansas, No. 2	80.03	6.37	7.96	55.0	3.50	3.73	3.62
5.	Arkansas, No. 3	76.37	8.72	11.41	44.0	3.83	3.46	4.02
6.	Colorado, No. 1	61.13	18.10	29.60	16.9	3.05	2.63	3.02
7.	Illinois, No. 1	62.01	20.93	33.73	16.8	3.52	3.36	3.64
8.	Illinois, No. 2	54.06	18.82	32.96	17.0	3.03	3.05	2.92
9.	Illinois, No. 3	67.30	15.14	22.50	24.4	3.69	3.49	3.62
10.	Illinois, No. 4	61.79	17.49	28.3	19.0	3.32	3.02	3.14
11.	Illinois, No. 5	58.02	17.35	29.9	18.2	3.16	3.02	3.32
12.	Illinois, No. 6	60.51	13.05	21.5	25.2	3.30	3.11	3.51
13.	Indiana, No. 1	62.20	19.53	31.4	17.6	3.44	3.33	3.63
14.	Indiana, No. 2	62.97	20.21	32.09	17.3	3.50	3.54	3.53
15.	Indian Territory, No. 1	69.85	19.80	28.34	19.0	3.76	3.72	3.84

* Trans. Am. Inst. Min. Eng., Vol. XXVII.—266-Y.
†U. S. Geol. Surv. Prof. Pap. 48.

From Report of Coal Testing Plant, St. Louis, 1904—Concluded.

Description.	Total carbon C.....	Volatile carbon vc..	Ratio $\frac{vc}{C}$.........	Reading from curve.	Hydrogen Values. Hydrogen from curve........	H. from ultimate analysis	H. from indicated calories
16. Indian Territory, No. 2	71.49	21.70	30.35	18.0	3.90	3.89	4.04
17. Indian Territory, No. 3	68.18	20.36	29.86	18.2	3.71	3.54	3.87
18. Indian Territory, No. 4	63.21	19.31	30.54	17.9	3.46	3.20	3.27
19. Indian Territory, No. 5	52.39	15.34	29.28	18.6	2.85	2.63	2.54
20. Iowa, No. 1	61.80	15.29	24.74	22.1	3.38	3.25	3.54
21. Iowa, No. 2	60.36	18.62	30.85	17.8	3.31	3.45	3.53
22. Iowa, No. 3	60.62	21.63	35.68	16.2	3.52	3.54	3.65
23. Iowa, No. 4	61.25	20.03	32.70	17.1	3.41	3.24	3.45
24. Iowa, No. 5	59.89	15.37	25.66	21.0	3.23	3.28	3.45
25. Kansas, No. 1	68.22	18.21	26.69	20.2	3.68	3.87	3.72
26. Kansas, No. 2	63.14	15.51	24.56	22.3	3.69	3.73	3.93
27. Kansas, No. 3	69.07	17.82	25.80	21.0	4.01	4.08	4.23
28. Kansas, No. 4	65.02	18.22	28.02	19.2	3.77	4.05	4.13
29. Kansas, No 5	71.90	16.93	23.54	23.4	3.96	4.04	4.12
30. Kentucky, No. 1	78.31	21.23	27.11	19.9	4.22	4.26	4.93
31. Kentucky, No. 2	67.64	21.37	31.59	17.5	3.74	3.75	4.43
32. Kentucky, No. 3	66.75	19.79	29.64	18.4	3.64	3.69	3.93
33. Kentucky, No. 4	66.50	19.71	29.63	18.4	3.63	3.48	3.92
34. Missouri, No. 1	60.00	19.23	32.05	17.3	3.33	3.58	3.53
35. Missouri, No. 2	56.25	17.23	30.63	17.9	3.08	3.07	3.31
36. Missouri, No. 3	54.79	15.68	28.61	18.9	2.98	2.98	2.86
37. Missouri, No. 4	72.45	27.98	38.61	17.0	4.75	4.50	4.71
38. Montana, No. 1	60.41	17.38	28.77	17.3	3.01	2.75	3.12
39. New Mexico, No. 1	64.34	17.44	27.10	18.4	3.21	3.09	3.31
40. New Mexico, No. 2	56.71	18.68	33.29	15.4	2.88	2.96	3.06
41. North Dakota, No. 1	52.66	19.05	36.17	12.6	2.40	1.83	2.13
42. North Dakota, No. 2	55.16	15.67	28.40	15.5	2.58	1.74	2.32
43. Texas, No. 1	52.06	23.06	44.2	11.2	2.58	2.38	2.81
44. Texas, No. 2	57.31	17.20	30.0	14.7	2.52	2.06	2.48
45. W. Virginia, No. 1	78.31	22.95	29.3	18.6	4.27	4.31	4.41
46. W. Virginia, No. 2	74.44	23.94	32.16	18.8	4.50	4.13	4.66
47. W. Virginia, No. 3	76.12	17.74	23.30	23.7	4.15	4.15	4.22
48. W. Virginia, No. 4	78.21	16.34	20.89	25.7	4.20	4.09	4.40
49. W. Virginia, No. 5	78.36	18.39	21.46	25.4	4.16	4.01	4.32
50. W. Virginia, No. 6	83.62	11.09	13.26	33.5	......	4.17	4.44
51. W. Virginia, No. 7	82.41	8.80	10.68	43.1	......	3.65	4.54
52. W. Virginia, No. 8	78.75	19.83	25.18	21.6	4.28	4.36	4.29
53. W. Virginia, No. 9	79.35	16.68	21.02	25.6	4.25	4.24	4.51
54. W. Virginia, No. 10	85.91	9.99	11.63	37.0	......	4.17	4.30
55. W. Virginia, No. 11	79.12	8.32	10.55	37.25	......	3.56	3.93
56. W. Virginia, No. 12	83.63	9.25	11.06	35.6	......	3.98	3.94
57 Wyoming, No. 1	58.41	18.85	32.27	15.8	2.98	2.47	2.96
58. Wyoming, No. 2	55.29	17.89	32.36	15.7	2.81	2.92	3.47

Part II.

Results by Lord and Haas*.

Upper Freeport Coal, Pennsylvania and Ohio.

1. East Palestine, Ohio	70.58	17.93	25.40	21.5	3.85	3.91	3.83
2. East Palestine, Ohio	73.23	21.91	29.92	18.2	3.99	4.05	3.98
3. Waterford, Ohio	74.39	21.05	28.30	19.1	4.02	4.18	3.97
4. Yellow Creek, Ohio	73.15	22.27	30.44	18.0	4.01	4.06	4.25
5. Steubenville, Ohio	74.73	23.19	31.03	17.5	3.96	4.25	4.06
6. Cambridge, Ohio	70.61	20.25	20.68	18.9	3.83	3.90	3.81
7. Steubenville, Ohio	71.40	22.10	30.95	17.6	3.89	3.29	3.70
8. Salineville, Ohio	72.62	19.82	27.29	19.6	3.78	4.02	3.87
9. Palestine, Ohio	71.29	20.59	28.88	18.7	3.85	3.84	4.22
10. N. Galilee, Pa	73.57	21.27	28.91	18.7	3.98	4.09	3.68
11. Palestine, Ohio	73.64	20.94	28.44	19.0	3.98	3.88	3.88
12. Average	72.65	21.02	28.93	18.7	3.93	3.94	3.93

*Trans. Amer. Inst. Min. Eng., Vol. XXVII.

Table VI, Part II—Concluded.

Pittsburg Coal, Pennsylvania.

	Description.	Total carbon C.....	Volatile carbon vc...	Ratio $\frac{vc.}{C.}$..........	Reading from curve.	Hydrogen Values. Hydrogen from curve.........	H. from ultimate analysis	H. from indicated calories
13.	Carnegie, Pa	77.20	21.00	27.19	19.8	4.16	4.20	4.09
14.	Turtle Creek, Pa.	76.56	19.97	26.21	20.6	4.11	4.35	4.08
15.	Carnegie, Pa	76.57	21.51	28.09	19.2	4.13	4.03	4.46
16.	Carnegie, Pa	73.50	21.50	29.25	18.6	4.00	4.18	4.06
17.	Creedmore	74.45	23.31	31.31	17.5	4.08	4.27	4 17
18.	N. Mansfield	73.91	21.26	28.56	19.0	4.04	4.04	3.88
19.	Turtle Creek	74.48	21.48	28.83	18.8	4.04	4.01	3.88
20.	Average	75.24	21.43	28.48	19.0	4.07	4.15	4.09

Middle Kittanning (Darlington Coal), Pennsylvania.

21.	Hoytdale	77.83	20.18	25.93	20.8	4.18	4.05	4.23
22.	Beaver Creek	74.60	19.18	25.71	21.0	4.03	4.03	3.73
23.	Wampum	77.93	22.16	28 44	19.0	4.21	4.18	4.27
24.	Near Wampum.	76.81	20.95	27.16	19.9	4.17	4.16	4.07
25.	Hoytdale	72.78	19.28	26.49	20.4	3.93	3.61	3.84
26.	Wampum	72.82	21.97	30.17	18.1	3.99	4.18	3.90
27.	Clinton	73.57	19.77	26.87	20.0	3.95	3.87	3.80
28.	Average	75.19	20.50	27.26	19.8	4.06	4.01	3.98

Middle Kittanning (Hocking Valley Coal) Ohio.

29.	Hocking Lump	69.42	19.10	27.51	19.6	3.74	3.32	3.58
30.	Run of mine	66.50	16.96	25.50	21.2	3.62	3 22	3.14
31.	Hocking lump	68.18	19 13	28 06	19.2	3.67	3.48	3.10
32.	Average	68.03	18.39	27.03	19.9	3.66	3.34	3.27

Thacker Coal, West Virginia.

33.	Run of mine	78.90	21.80	27.63	19.5	4.25	4.28	3.96
34.	Nut coal	78.40	22.15	28.25	19.2	4.25	4.25	4.34
35.	Average	78.65	21.98	27.94	19.3	4.25	4.27	4.15

Pocahontas Coal.

36.	Run of mine	83.75	10.10	12.06	36.73	3.71	3.80	3.71
37.	Run of mine	85.46	10.34	12.09	35.5	3.67	3.85	3.67
38.	Run of mine	85.40	9.65	10.13	40.7	3.93	3.90	3.93
39.	Average	84.87	10.03	11.81	37.8	3.77	3.85	3.77

Mahoning Coal.

40	Salineville, O	71.13	20.18	28.37	19.1	3.85	3.74	3.60

Table VI, Part III—Concluded.

*Michigan Coals**.

Description.	Total carbon C......	Volatile carbon vc...	Ratio $\frac{vc}{C}$..........	Reading from curve.	Hydrogen Values. Hydrogen from curve	H. from ultimate analysis	H. from indicated calories.
1. Michigan, No. 1	71.11	17.16	24.13	22.8	3.91	3.64	3.74
2. Michigan, No. 2	71.67	17.87	24.93	21.9	3.91	3.84	3.87
3. Michigan, No. 3	71.37	18.79	26.33	20.6	3.87	3.33	3.88
4. Michigan, No. 4	72.88	19.92	27.33	19.8	3.94	3.81	3.80
5. Michigan, No. 5	73.55	28.27	38.43	15.5	4.38	4.72	4.45
6. Michigan, No. 6	72.42	27.78	38.36	15.6	4.33	4.67	4.59
7. Michigan, No. 7	65.87	24.71	37.51	17.2	4.25	4.24	4.01
8. Michigan, No. 8	68.33	23.18	33.92	18.2	4.22	4.17	4.46
9. Michigan, No. 9	68.07	22.01	32.34	18.8	4.14	4.62	4.17
10. Michigan, No. 10	62.29	20.62	33.10	18.4	3.79	3.77	4.32
11. Michigan, No. 11	63.57	21.41	33.68	18.2	3.90	3.99	4.15
12. Michigan, No. 12	73.09	23.75	32.49	18.7	4.44	3.90	4.51

A graphic illustration of the relative values obtained as in table VI. is shown in figure 9. The values for hydrogen, calculated from the indicated calories, have been arranged serially to correspond with the numbers in table VI., represented by the straight line. The hydrogen as developed from ultimate analysis ($H - \frac{O}{8}$) is located above or below this point in tenths of a per cent and indicated by a dot, connected by a continuous line.

The hydrogen as indicated by the curve is similarly located with reference to the hydrogen from indicated calories and is shown by the small circle, connected by a dotted line. It should be noted that divisions above and below indicate variation of 0.1%. Divisions horizontally are without significance. The figures at the lower margin of the chart refer to the corresponding analysis in table VI. Alternate numbers only have been taken as being sufficient for the purpose of illustration. The complete comparison is available in table VI.

*Michigan Geol. Surv., Vol. VIII., pp. 107-119.

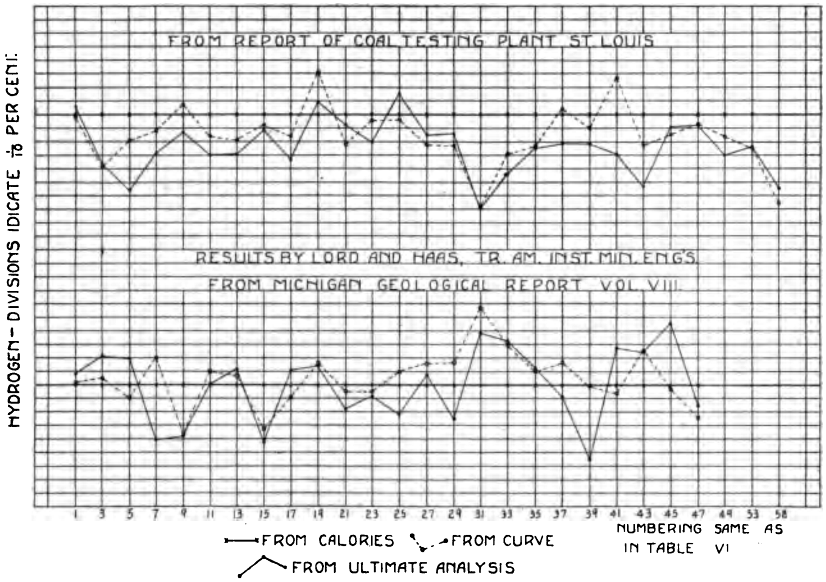


FIG. 9.—Comparison of the values of available hydrogen as determined by various methods.

In the above table we have tested the adaptability of the curve to upwards of one hundred samples of coal widely distributed throughout the United States. In comparing the available hydrogen thus developed with the hydrogen obtained by ultimate analysis, it would appear that the results on the average are quite as accurate as those by the latter process. Whether this will satisfy all the uses to which the factor for available hydrogen is desired, may not now enter into the question. It seems fair, however, to assume that it may be made use of in developing the factor for the non-combustible part of the volatile matter.

INERT VOLATILE MATTER.

If now we have the available hydrogen and assuming that we have the total carbon, together with the usual data of a proximate analysis, the inert volatile matter may be found by subtracting from 100% the sum of the total carbon, available hydrogen, sulphur, ash and water. To have any value for comparison, however, this remainder should be reduced to the pure, or ash and water free coal, by dividing by one hundred, minus the ash and water. To illustrate the use of this factor the same coals as in table VI. have been tabulated, giving

the usual results as obtained by proximate analysis, and by addition of the factor for total carbon, deducing the column for the hydrogen, the carbon ratio and the inert volatile matter.

TABLE VII.

PART I.

From Report of Coal-Testing Plant, St. Louis, 1904.

Description.	Proximate Analysis.				Additional Factors.			Deduced Values.		
	Moisture..	Volatile matter.	Fixed carbon ..	Ash............	Sulphur	Total carbon...	Volatile carbon.	Hydrogen from curve........	Ratio $\frac{vc}{C}$......	Inert volatile—pure coal basis.........
1. Alabama, No. 1	1.55	32.10	53.71	12.64	0.73	72.16	18.45	3.90	25.56	10.51
2. Alabama, No. 2	2.58	33.15	51.74	12.53	1.02	69.24	17.50	3.78	25.27	12.77
3. Arkansas, No. 1	1.17	17.83	68.12	12.88	1.27	75.68	7.56	3.40	10.0	6.51
4. Arkansas, No. 2	0.74	16.26	73.66	9.34	1.90	80.03	6.37	3.50	7.96	4.55
5. Arkansas, No. 3	0.80	19.75	67.65	11.80	1.30	76.37	8.72	3.83	11.41	6.75
6. Colorado, No. 1	13.49	37.11	43.03	6.37	0.58	61.13	18.10	3.05	29.60	19.19
7. Illinois, No. 1	6.28	38.92	41.08	13.72	4.25	62.01	20.93	3.52	33.73	12.77
8. Illinois, No. 2	5.31	34.29	36.24	24.16	4.30	54.06	17.82	3.03	32.96	12.95
9. Illinois, No. 3	5.96	30.29	52.16	11.59	1.77	67.30	15.14	3.69	22.50	11.75
10. Illinois, No. 4	11.40	32.45	44.30	11.85	1.34	61.79	17.49	3.32	28.3	13.41
11. Illinois, No. 5	5.16	34.98	40.67	19.19	3.76	58.02	17.35	3.16	29.9	14.15
12. Illinois, No. 6	5.13	32.68	47.46	14.73	4.45	60.51	13.05	3.30	21.5	14.82
13. Indiana, No. 1	8.66	34.86	42.67	13.81	2.58	62.20	19.53	3.44	31.4	12.00
14. Indiana, No. 2	6.24	37.49	42.76	13.51	4.60	62.97	20.21	3.50	32.09	11.44
15. Indian Territory, No. 1	3.87	35.73	50.05	10.35	1.99	69.85	19.80	3.76	28.34	11.86
16. Indian Territory, No. 2	1.70	37.19	49.79	11.32	1.56	71.49	21.70	3.90	30.35	11.53
17. Indian Territory, No. 3	3.45	37.45	47.82	11.28	3.67	68.18	20.36	3.71	29.86	11.38
18. Indian Territory, No. 4	4.91	37.79	43.90	13.40	4.02	63.21	19.31	3.46	30.54	13.46
19. Indian Territory, No. 5	5.74	31.46	37.05	25.75	4.06	52.39	15.34	2.85	29.28	13.44
20. Iowa, No. 1	5.21	31.76	46.51	16.52	5.20	61.80	15.29	3.38	24.74	10.08
21. Iowa, No. 2	4.25	37.02	41.74	16.99	5.20	60.36	18.62	3.31	30.85	12.56
22. Iowa, No. 3	4.52	40.96	38.99	15.53	6.83	60.62	21.63	3.52	35.68	11.23
23. Iowa, No. 4	10.03	37.27	41.22	11.48	4.46	61.25	20.03	3.41	32.70	11.93
24. Iowa, No. 5	9.22	32.71	44.52	13.55	3.42	59.89	15.37	3.23	25.66	13.84
25. Kansas, No. 1	3.74	33.11	50.01	13.14	4.34	68.22	18.21	3.68	26.69	8.27
26. Kansas, No. 2	2.23	31.87	47.63	18.27	6.40	63.14	15.51	3.69	24.56	7.88
27. Kansas, No. 3	2.50	33.80	51.25	12.45	5.68	69.07	17.82	4.01	25.80	7.51
28. Kansas, No. 4	3.57	37.00	46.80	12.63	8.33	65.02	18.22	3.77	28.02	7.97
29. Kansas, No. 5	1.84	32.40	54.97	10.79	3.86	71.90	16.93	3.96	23.54	8.75
30. Kentucky, No. 1	1.92	36.56	57.08	4.44	1.24	78.31	21.23	4.22	27.11	10.54
31. Kentucky, No. 2	5.36	38.99	46.27	9.38	3.72	67.64	21.37	3.74	31.59	11.91
32. Kentucky, No. 3	5.85	36.90	46.96	10.29	3.60	66.75	19.79	3.64	29.64	11.76
33. Kentucky, No. 4	2.54	36.08	46.79	14.59	4.67	66.50	19.71	3.63	29.63	9.73
34. Missouri, No. 1	3.50	35.35	40.77	20.38	5.53	60.00	19.23	3.33	32.05	9.53
35. Missouri, No. 2	9.14	34.53	39.02	17.31	5.30	56.25	17.23	3.08	30.63	12.12
36. Missouri, No. 3	5.51	32.08	39.11	23.30	4.13	54.79	15.68	2.98	28.61	13.05
37. Missouri, No. 4	5.39	44.91	44.47	5.23	5.55	72.45	27.98	4.75	38.61	7.41
38. Montana, No. 1	9.05	36.70	43.03	11.22	1.76	60.41	17.38	3.01	28.77	18.25
39. New Mexico, No. 1	10.86	35.14	46.90	7.10	.64	64.34	17.44	3.21	27.10	16.88
40. New Mexico, No. 2	8.13	34.82	37.83	19.22	1.30	56.71	18.68	2.88	33.29	16.18
41. North Dakota, No. 1	15.42	38.73	33.61	12.24	2.02	52.66	19.05	2.40	36.17	21.09
42. North Dakota, No. 2	16.70	37.10	39.49	6.71	.63	55.16	15.67	2.58	28.40	23.79
43. Texas, No. 1	13.40	42.75	29.00	14.85	1.04	52.06	23.06	2.58	44.20	22.39
44. Texas, No. 2	10.66	39.42	40.11	9.81	.71	57.31	17.20	2.52	30.00	23.90
45. West Virginia, No. 1	1.35	36.92	55.36	6.37	.90	78.31	22.95	4.27	29.30	9.53
46. West Virginia, No. 2	1.46	40.14	50.50	7.90	3.50	74.44	23.94	4.50	32.16	9.44
47. West Virginia, No. 3	1.00	30.25	58.38	10.37	1.07	76.12	17.74	4.15	23.30	8.22
48. West Virginia, No. 4	98	28.72	61.87	8.43	.90	78.21	16.34	4.20	20.89	8.03
49. West Virginia, No. 5	.65	29.20	59.97	10.18	.99	76.36	18.39	4.16	21.46	8.62

Table VII—Continued.

	Description.	Proximate Analysis.				Additional Factors.			Deduced Values.		
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Total carbon.	Volatile carbon.	Hydrogen from curve.	Ratio VC/C.	Inert. volatile—pure coal basis.
50.	West Virginia, No. 6	.64	21.74	72.53	5.09	.66	83.62	11.09	4.17	13.26	6.17
51.	West Virginia, No. 7	.76	20.54	73.01	5.09	1.20	82.41	8.80	3.65	10.68	7.35
52.	West Virginia, No. 8	1.60	32.12	58.92	7.36	.92	78.75	19.83	4.28	25.18	7.78
53.	West Virginia, No. 9	1.01	29.53	62.67	6.79	.80	79.35	16.68	4.25	21.02	8.46
54.	West Virginia, No. 10	.65	18.80	75.92	4.63	.57	85.91	9.99	4.17	11.63	4.28
55.	West Virginia, No. 11	.80	16.90	70.80	11.50	.53	79.12	8.32	3.56	10.55	5.10
56.	West Virginia, No. 12	.62	18.05	74.38	6.95	.69	83.63	9.25	3.98	11.06	4.47
57.	Wyoming, No. 1	17.69	37.96	39.56	4.79	263	58.41	18.85	2.98	32.27	19.99
58.	Wyoming, No. 2	2.73	37.61	37.40	22.26	4.17	55.29	17.89	2.81	32.36	17.00

Part II.

Results by Lord and Haas, Tr. Am. Inst. Min. Eng., Vol. 27.

Upper Freeport Coal, Ohio and Pennsylvania.

1.	East Palestine, O	.82	34.98	52.65	11.89	3.65	70.58	17.93	3.85	25.40	10.54
2.	East Palestine, O	1.65	37.45	51.32	9.58	1.75	73,23	21.91	3.99	29.92	11.28
3.	Waterford, O	1.55	37.29	53.34	7.82	3.44	74.39	21.05	4.02	28.30	9.68
4.	Yellow Creek, O	1.23	38.72	50.88	9.17	3.89	73.15	22.27	4.01	30.44	9.52
5.	Steubenville, O	1.47	39.23	51.54	7.66	2.85	74.73	23.19	3.96	31.03	10.26
6.	Cambridge, O	2.43	37.79	50.36	9.42	3.01	70.61	20.25	3.83	20.68	12.25
7.	Steubenville, O	2.40	39.20	49.30	9.10	3.00	71.40	22.10	3.89	30.95	11.53
8.	Salineville, O	2.80	36.30	52.80	8.10	3.00	72.62	19.82	3.78	27.29	10.99
9.	Palestine, O	2.15	36.70	50.70	10.45	2.64	71.29	20.59	3.85	28.88	11.00
10.	N. Galilee, Pa	2.30	36.70	52.80	8.70	2.24	73.57	21.27	3.98	29.91	10.34
11.	Palestine, O	2.45	36.60	52.70	8.25	2.34	73.64	20.94	3.98	28.44	10.45
12.	Average	1.93	37.35	51.63	9.10	2.89	72.65	21.02	3.93	28.93	10.67

Pittsburg Coal, Pennsylvania.

13.	Carnegie, Pa	1.45	36 42	56.20	5.93	1.42	77.20	21.00	4.16	27.19	10.62
14.	Turtle Creek	1.08	34.38	56.59	7.95	1.60	76.56	19.97	4.11	26.21	9.56
15.	Carnegie	1.07	37.79	55.06	6.08	1.76	76.57	21.51	4.13	28.09	11.19
16.	Carnegie	1.08	37.67	52.00	9.25	2.54	73.50	21.50	4.00	29.25	9.62
17.	Creedmore	1 09	38.91	51.14	8.86	1.80	74.45	23.31	4.08	31.31	10.91
18.	North Mansfield	2.10	36.20	52.65	9.05	1.77	73.91	21.26	4.04	28.56	10.27
19.	Turtle Creek	1.75	36,20	53.00	9.05	1.66	74.48	21.48	4.04	28.83	10.11
20.	Average	1.37	36.80	53.81	8.02	1.79	75.24	21.43	4.07	28.48	10.49

Middle Kittanning (Darlington Coal), Pennsylvania.

21.	Hoytdale	1.60	36.40	57.65	4.35	1.57	77.83	20.18	4.19	25.93	12.18
22.	Beaver Creek	1.50	34.33	55.42	8.75	1.96	74.60	19.18	4.03	25.71	10.20
23.	Wampum	0.75	38.53	55.77	4.95	2.35	77.93	22.16	4.21	28.44	10.40
24.	Near Wampum	0.70	36.80	55.85	6.65	1.18	76.81	20.95	4.17	27.16	11.32
25.	Hoytdale	2.70	35.10	53.50	8.70	1.68	72.78	19.28	3.93	26.49	11.52
26.	Wampum	2.85	37.50	50.85	8.80	3.25	72.82	21.97	3 99	30.17	9.27
27.	Clinton	2.55	35.60	53.80	8.05	1.86	73.57	19.77	3.95	26.87	11.20
28.	Average	1.81	36.32	54.69	7.18	1.98	75.19	20.50	4.06	27.26	10.74

Middle Kittanning (Hocking Coal), Ohio.

29.	Hocking lump	6.72	37.13	50.32	5.83	1.67	69.42	19.10	3.74	27.51	14.54
30.	Run of mine	6.65	34.14	49.54	9.67	1.67	66.50	16.96	3.62	25.50	11.30
31.	Hocking lump	6.40	36.05	49.05	8.50	1.43	68.18	19.13	3.67	28.06	13.77
32.	Average	6.59	35.77	49.64	8.00	1.59	68.03	18.39	3.66	27.03	14.32

Table VII—Concluded.

Thacker Coal, West Virginia.

Description.	Proximate Analysis.				Additional Factors.			Deduced Values.		
	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Total carbon.	Volatile carbon.	Hydrogen from curve	Ratio $\frac{VC}{C}$.	Inert volatile—pure coal basis.
33. Run of mine	1.40	35.00	57.10	6.50	1.16	78.90	21.80	4.25	27.63	8.45
34. Nut coal	1.35	36.35	56.25	6.05	1.40	78.40	22.15	4.25	28.25	9.23
35. Average	1.38	35.68	56.67	6.27	1.28	78.65	21.98	4.25	27.94	8.84
Mahoning Coal.										
36. Salineville, O	3.15	35.00	50.95	10.90	1.86	71.13	20.18	3.85	28.37	10.59
Part III.										
From Michigan Geological Report, Vol. VIII.—Michigan Coals.										
1. Michigan, No. 1	10.15	33.14	53.95	2.76	1.10	71.11	17.16	3.91	24.13	12.60
2. Michigan, No. 2	10.67	33.59	53.80	1.94	1.01	71.67	17.87	3.91	24.93	12.36
3. Michigan, No. 3	7.79	34.74	52.58	4.89	1.01	71.37	18.79	3.87	26.33	12.67
4. Michigan, No. 4	7.58	35.70	52.96	3.76	1.50	72.88	19.92	3.94	27.33	11.66
5. Michigan, No. 5	5 58	46.73	45.28	2.41	2.83	73 55	28 27	4.38	38.43	12.22
6. Michigan, No. 6	5.93	46.59	44.64	2.84	3.07	72.42	27.78	4.33	38.36	12.56
7. Michigan, No. 7	8.71	38.45	41.16	11.68	2.72	65.87	24.71	4.25	37.51	8.50
8. Michigan, No. 8	5.82	39.79	45.15	9.24	3.83	68.33	23.18	4.22	33.92	10.19
9. Michigan, No. 9	6.09	39.54	46.06	8.26	5.72	68.07	22.01	4.14	32.34	9.40
10. Michigan, No. 10	5.01	39.62	41.67	13.70	6.66	62.29	20.62	3.79	33.10	10.51
11. Michigan, No. 11	4.52	40.57	42.16	12.75	6.92	63.57	21.41	3.90	33.68	10.08
12. Michigan, No. 12	3.78	41.18	49.34	5,70	2.50	73.09	23.75	4.44	32.49	11.58

CLASSIFICATION OF COALS.

In the discussion that has preceded, the attempt has been made to illustrate the progressive nature of the decomposition that has resulted in coal as we find it. The fundamental properties of the material, those which relate to quality and behavior are directly involved in the ratios and percentages of the decomposition products as already outlined. A scheme of classification, therefore, to have any intelligent significance should be an expression of these properties. It should be susceptible of practical or commercial interpretation and at the same time be based on scientific data.

The scheme of classification at present most widely recognized is that proposed by Fazer.* It has the merit of being intelligible from

* Trans. Amer. Inst. Ming. Engrs., Vol. VI, p. 430.

the industrial standpoint. It does not, however, embody certain phases that seem desirable from the standpoint of our discussion thus far. Indeed, in his recent admirable defense of this classification,* he says:

"I emphasized the importance of separating the water from the volatile combustible matter before attempting the calculation of a fuel ratio and subsequent classification. That this subtraction was not embodied in any of my tables was, because there were no data from which to obtain it."

The method of classification herein proposed makes prominent use of that part of the volatile matter which is variously designated as inert or non-combustible, or as "water of composition." But this factor alone would be misleading unless taken in conjunction with some of the ratios expressive of the relation between the carbons as indicated by their behavior under process of destructive distillation. It is proposed by Campbell† to base a classification on the ratio of the total carbon divided by the total hydrogen. The argument for the use of the total hydrogen in such a ratio seems illogical and at variance with all the facts attending the property of coals. Especially is this true at the lignitic end of the series. Certain it is that the hydrogen there has a different meaning from what it has at the semi-bituminous end. To include the hydrogen of the moisture is to build on a variable that would make it impossible for any one else to reproduce the classification who could not duplicate the exact method of sampling and transmission. With the finely drawn distinctions in the resulting ratios a sample of coal might fall into as many different classes as there were analysts who examined it. It fails also to make use of one valuable fact developed by the usual method of proximate analysis, and that is, the relation of the volatile hydrocarbons to the total carbonaceous material. This, it would seem, comprises such fundamental properties, both with reference to its chemical structure and to its performance in actual use, that no system of classification could have much value that ignores it. These objections all become accentuated when samples approach the lignitic type. It does not seem possible that these divisions can be properly considered without taking into account the factor for combined water, the "residual cellulose" if we may so designate it. On this point again we quote from Frazer§:

* Bulletin Amer. Inst. Ming. Engrs., March, 1906.

† Report of Coal Testing Plant, U. S. Geol. Survey, St. Louis; Prof. Pap. U. S. Geol. Survey, No. 48, Pt. 1, pp. 156-173.

§ Bulletin Amer. Inst. Ming. Engrs., March, 1906, p. 244-245.

"It may well be that other factors than carbon and hydrogen will some day furnish the means of a further differentiation of lignites, brown coals. peats, and cannel coals." This seems to be thoroughly borne out by a study of the part this water of hydration or inert volatile matter plays as set forth in the preceding tables.

It is proposed, therefore, to base a classification on the divisions indicated in Fig. 8, and in tables VI. and VII. Above the bituminous type, the classes are distinguished by the carbon ratios only, $\frac{vc}{C}$ in which "vc" is the volatile carbon unassociated with hydrogen, and "C" is the total carbon as determined by analysis. Within the bituminous type when the ratio reaches approximately 30%, the differentiation into black and brown lignites is made by bringing into the consideration the percentage constituents on the pure coal or "ash and water free" basis of the water of composition or inert volatile matter.

Briefly outlined, the plan proposes to retain the old nomenclature but to base the divisions upon the ratio $\frac{vc}{C}$. As an illustration of the argument for this ratio it may be noted that it seems to surpass other proposed ratios in the sharpness of distinctions at both ends of the table. For example, no sample is met with in either the St. Louis report or the results of Lord and Haas, as listed in table VII. where the ratio $\frac{vc}{C}$ occurs between 15% and 20%, thus indicating a positive line of demarkation between these classes. The semi-bituminous class groups very closely about a ratio of 10 to 11%; while the bituminous class in no instance drops below a ratio of 20%. The subdivisions of the bituminous type are made primarily with reference to the carbon ratios, but with further reference to the percentage in the pure coal of the non-combustible volatile matter. That is, subdivisions A and B have their carbon ratios between 20 and approximately 30%; but A represents the richer coals in volatile combustible as shown by the lower percentages of inert volatile matter, being below 10%, while B includes the leaner sort, having above 10% of inert volatile. Similarly subdivision C represents the coals richer in volatile matter and are located with reference to their available hydrogen by the subsidiary curve "b". They have a high carbon ratio, from 32% to 44% and an inert ratio of below 10%. The subdivision D has

approximately the same carbon ratio but an inert ratio of from 10% to 16%. The further increase in this latter ratio marks a type of sufficient distinctness to be classified separately as lignites. Here again, by making use of the inert volatile percentage, this class subdivides rather sharply into the black lignites, having from 16% to 20% of combined water, while the brown lignites have above 20% of that constituent. The tabulation of the coal results from the St. Louis Testing-Plant afford further illustration of this scheme.

The coals listed under the final subdivisions are arranged with reference to the inert volatile matter, but that factor should not determine altogether their order in the several classes. Here probably should come in the notion of value as determined by some factor which would involve all the elements. Probably a better arrangement would be to list, therefore, in the order of their calorific values in the final class subdivisions. All ratios in the tables are given in percentage form.

PROPOSED OUTLINE FOR CLASSIFICATION OF COALS.

- Coals......
  - Anthracitic...
    - Anthracites Proper ...... Ratio $\frac{vc}{C}$ below 4%.
    - Semi-Anthracite.......... Ratio $\frac{vc}{C}$ between 4% and 8%.
    - Semi-Bituminous........ Ratio $\frac{vc}{C}$ from 10% to 15%.
  - Bituminous...
    - Bituminous Proper ......
      - A
        - Ratio $\frac{vc}{C}$ from 20% to 32%.
        - Inert Volatile from 5% to 10%.
      - B
        - Ratio $\frac{vc}{C}$ from 20% to 27%.
        - Inert Volatile from 10% to 16%.
      - C
        - Ratio $\frac{vc}{C}$ from 32% to 44%.
        - Inert Volatile from 5% to 10%.
      - D
        - Ratio $\frac{vc}{C}$ from 27% to 44%.
        - Inert Volatile from 10% to 16%.
    - Black Lignites ....
      - Ratio $\frac{vc}{C}$ from 27% up.
      - Inert Volatile from 16% to 20%.
    - Brown Lignites ....
      - Ratio $\frac{vc}{C}$ from 27% up.
      - Inert Volatile from 20% to 30%.

CLASSIFICATION OF COALS, ST. LOUIS TESTING PLANT, FIRST REPORT.

TABLE VIII.

Anthracites.

Ratio $\frac{vc}{C}$ below 4%.

Semi-Anthracites.

Ratio $\frac{vc}{C}$ between 4% and 8%.

		$\frac{vc}{C}$	Inert. Vol.
	Arkansas No. 5	4.66	....
4.	Arkansas No. 2	7.96	....

Semi-Bituminous.

Ratio $\frac{vc}{C}$ from 10% to 15%.

3.	Arkansas No. 1	10.00	....
55.	West Virginia No. 11	10.55	....
51.	West Virginia No. 7	10.68	....
56.	West Virginia No. 5	11.06	....
5.	Arkansas No. 3	11.41	....
54.	West Virginia No. 10	11.63	....
50.	West Virginia No. 6	13.26	....

Bituminous—Class A.

$\frac{vc}{C}$ 20% to 32%. Inert. vol 5% to 10%.

49.	West Virginia No. 5	21.46	6.33
27.	Kansas No. 3	25.80	7.51
52.	West Virginia No. 8	25.18	7.78
26.	Kansas No. 2	24.56	7.88
28.	Kansas No. 4	28.02	7.97
48.	West Virginia No. 4	20.89	8.03
47.	West Virginia No. 3	23.30	8.22
25.	Kansas No. 1	26.69	8.27
53.	West Virginia No. 9	21.02	8.46
29.	Kansas No. 5	23.54	8.75
45.	West Virginia No. 1	29.30	9.53
33.	Kentucky No. 4	29.63	9.73

Bituminous—Class B.

$\frac{vc}{C}$ 20% to 27%. Inert. vol. 10% to 16%.

20.	Iowa No. 1	24.74	10.08
1.	Alabama No. 1	25.56	10.51
30.	Kentucky No. 1	27.11	10.54
9.	Illinois No. 3	22.50	11.75
2.	Alabama No. 2	25.27	12.77
24.	Iowa No. 5	25.66	13.34
12.	Illinois No. 6	21.50	14.83

Bituminous—Class C.

$\frac{vc}{C}$ 32% to 44%. Inert. vol. 5% to 10%.

37.	Missouri No. 4	38.61	7.41
46.	West Virginia No. 2	32.16	9.44
34.	Missouri No. 1.	32.05	9.53

Bituminous—Class D.

$\frac{VC}{C}$ 27% to 44%. Inert. vol. 10% to 16%.

		$\frac{VC}{C}$	Inert. Vol.
22.	Iowa No. 3	35.68	11.23
17.	Indian Territory No. 3	29.86	11.36
14.	Indiana No. 2	32.09	11.44
16.	Indian Territory No. 2	30.35	11.53
32.	Kentucky No. 3	29.64	11.76
15.	Indian Territory No. 1	28.34	11.86
31.	Kentucky No. 2	31.59	11.91
23.	Iowa No. 4	32.70	11.93
13.	Indiana No. 1	31.40	12.00
35.	Missouri No. 2	30.63	12.12
21.	Iowa No. 2	30.85	12.56
7.	Illinois No. 1	33.73	12.77
8.	Illinois No. 2	32.96	12.95
36.	Missouri No. 3	28.61	13.05
10.	Illinois No. 4	28.30	13.41
19.	Indian Territory No. 5	29.28	13.44
18.	Indian Territory No. 4	30.54	13.46
11.	Illinois No. 5	29.90	14.15

Black Lignites.

$\frac{VC}{C}$ 27% up. Inert. vol. 16% to 20%.

40.	New Mexico No. 2	33.29	16.18
39.	New Mexico No. 1	27.10	16.88
53.	Wyoming No. 2	32.36	17.00
38.	Montana No. 1	28.77	18.25
6.	Colorado No. 1	29.60	19.19
52.	Wyoming No. 1	32.27	19.99

Brown Lignites.

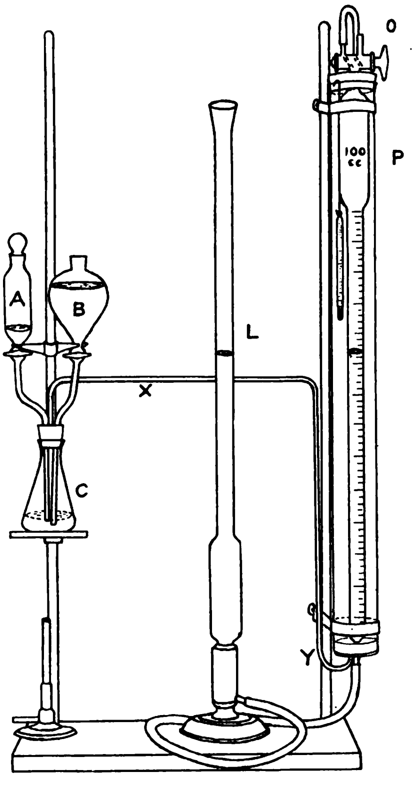
$\frac{VC}{C}$ 27% up. Inert. vol. 20% to 30%.

41.	North Dakota No. 1	36.17	21.09
41.	Texas No. 1	44.20	22.39
42.	North Dakota No. 2	28.40	23.79
44.	Texas No. 2	30.00	23.90

METHODS OF ANALYSIS.

TOTAL CARBON.

It is evident from what has preceded that a ready method must be available for the determination of the total carbon in coal. Without this factor, we have made no progress; with it, we have at hand as full information as would come from an ultimate analysis. However, if this factor must be obtained by the usual combustion method, we



APPARATUS FOR TOTAL CARBON DETERMINATION.
FIGURE 10.

have made but little advance by the mere development of the above ratio. It is proposed to obtain the factor for the total carbon by means of the apparatus shown in figure 10.

Combustion of the coal is effected in a closed bomb as in the calorimetric process described further on, by use of sodium peroxide,

WEIGHT OF

IN MILLIGRAMS PER CUBIC

CALCULATED FROM .0019641 = WT OF CO_2 AT 41° LATITUDE,

t° \ mm	720	722	724	726	728	730	732	734	736	738	740	742	744
10 Log.	4825 .68351	.4839 .68474	.4852 .68596	4866 .68717	.4880 .68838	.4893 .68959	.4907 .69080	.4920 .69200	.4934 .69320	.4948 .69439	.4960 .69552	.4974 .69671	.4988 .69790
11	.4802 .68143	.4816 .68266	.4829 .68388	.4843 .68509	.4856 .68631	.4870 .68752	.4883 .68872	.4897 .68993	.4911 .69113	.4924 .69232	.4938 .69352	.4951 .69471	.4965 .69590
12	.4780 .67947	.4794 .68070	.4808 .68192	.4821 .68314	.4834 .68435	.4848 .68556	.4862 .68677	.4875 .68798	.4889 .68918	.4902 .69038	.4915 .69157	.4929 .69276	.4942 .69395
13	.4758 .67746	.4772 .67869	.4785 .67991	.4799 .68113	.4812 .68235	.4826 .68356	.4839 .68477	.4853 .68598	.4866 .68718	:4880 :68838	.4892 .68951	.4906 .69071	.4919 .69190
14	.4736 .67539	.4749 .67662	.4763 .67784	.4776 .67906	.4789 .68028	.4803 .68150	4816 .68271	.4830 .68391	.4843 .68512	.4856 .68632	.4869 .68746	.4883 .68865	.4896 .68984
15	.4713 .67332	4727 67455	.4740 .67577	.4753 .67699	.4767 .67821	.4780 .67943	.4793 .68064	.4807 .68185	.4820 .68316	.4833 68426	.4846 .68540	.4859 .68659	.4873 .68779
16	.4690 .67119	.4704 .67242	.4717 .67365	.4730 .67487	.4743 .67609	.4757 .67731	.4770 .67853	4783 .67974	.4797 .68094	4810 .68215	.4823 .68335	4837 .68455	.4850 .68574
17	.4667 .66907	4681 67031	.4694 .67154	4707 67276	.4720 .67398	4734 .67520	4747 .67642	.4760 .67763	.4774 .67784	.4787 .68005	.4799 .68119	.4813 .68239	.4826 .68358
18	.4645 .66696	4658 .66819	.4671 .66942	4684 .67065	.4698 .67187	.4711 .67309	.4724 67431	.4737 .67553	.4751 .67674	4764 .67794	.4776 .67909	.4789 .68029	.4803 .68149
19	.4622 .66479	.4635 .66602	4648 .66726	.4661 .66849	.4674 .66971	.4687 .67093	.4701 .67215	4714 .67337	.4727 .67458	.4740 .67379	.4753 67694	.4766 .67814	.4779 .67934
20	.4597 .66249	.4610 .66373	.4623 66496	.4637 .66620	.4650 .66742	.4663 .66865	.4676 .66987	.4689 .67109	.4702 .67230	.4715 .67351	.4728 67472	.4742 .67593	.4755 .67713
21	.4573 .66020	.4586 .66144	4599 .66268	.4612 .66392	.4625 .66515	4638 .66637	.4652 .66760	.4665 .66882	.4678 .67003	.4691 .67125	.4704 .67246	.4717 .67366	.4730 .67487
22	.4550 .65804	.4563 .65928	.4576 .66052	.4589 .65176	.4602 .66299	.4616 .66422	.4628 .66544	.4642 .66667	.4655 .66789	.4668 .66910	.4680 .67025	.4693 .67146	.4706 .67267
23	.4526 .65570	.4539 .65694	.4552 .65818	.4565 .65942	.4578 .66066	.4591 .66189	.4604 .66312	.4617 .66434	.4630 .66556	.4643 .66678	.4655 .66793	.4668 .66915	.4681 .67035
24	.4501 .65329	.4514 .65454	.4527 .65578	.4540 .65702	.4553 .65826	.4566 .65950	.4579 .66073	.4591 .66195	.4605 .66318	.4618 .66440	.4630 .66561	.4643 .66683	.4656 .66804
25	.4476 .65089	.4489 .65214	.4502 .65339	.4515 .65463	.4528 .65587	.4541 .65711	.4553 .65834	.4566 .65957	.4579 .66085	.4592 .66202	.4605 66324	.4618 .66446	.4631 .66567
26	.4451 .64849	.4464 .64974	.4477 .65099	.4490 .65224	.4503 .65348	.4516 .65472	.4529 .65596	.4541 .65719	.4554 .65842	.4567 .65965	.4579 .66081	.4592 .66203	.4605 .66324
27	.4426 .64603	.4439 .64729	.4452 .64854	.4465 .64979	.4478 .65104	.4490 .65228	.4503 .65352	.4516 .65476	.4529 .65599	.4542 65722	.4554 .65838	.4567 .65960	.4579 .66082
28	.4401 .64351	.4414 .64477	.4426 .64603	.4439 .64728	.4453 .64853	.4465 .64978	.4477 .65102	.4490 .65226	.4503 .65349	.4516 .65472	.4528 .65589	.4541 .65711	.4553 .65833
29	.4374 .64094	.4387 .64220	.4400 .64346	.4413 .64472	.4426 .64597	.4438 .64722	.4451 .64846	.4464 .64970	.4476 .65094	.4489 .65217	.4501 .65334	.4514 .65457	.4527 .65580
30	.4348 .63829	.4361 .63956	.4373 .64082	.4386 .64208	.4399 .64334	.4412 .64459	.4424 .64584	.4437 .64708	.4450 .64832	.4462 .64956	.4474 .65073	.4487 .65197	.4500 .65319

WEIGHT OF CARBON IN VARIABLE

TABLE X.

Determination of Volatile Matter, Sandoval, Ill., Coal.

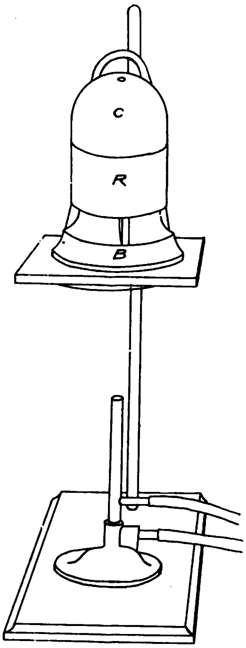
Large Bunsen burner Flame 20 cm. high Plat. crucible, Time 7 min	Highest Lowest Variation Average of eight	37.21 35.71 1.50 36.52	per cent. per cent.
Small Bunsen burner Flame 20 cm. high Plat. crucible, Time 7 min.	Highest Lowest Variation Average of eight	36.73 35.69 1.04 36.13	per cent. per cent.
Bunsen flame 3½ min Blast flame 3½ min Plat. crucible	Highest Lowest Variation Average of fourteen	37.78 36.53 1.25 37.13	per cent. per cent.
Bunsen flame, 3½ min. Blast flame 3½ min Porcelain crucible in special furnace	Highest Lowest Variation Average of nine	37.35 36.69 .66 37.10	per cent. per cent.

From this table it appears feasible to replace the expensive platinum crucible with one of porcelain. The serious deterioration of platinum under the combined effect of red-hot carbon and sulphur makes this end a very desirable one, even if there were no advantage in the results. On this latter point there is much to be said in favor of the porcelain crucible. The initial heating up is somewhat more gradual. A bright red is very easily reached and evenly maintained and especially is it true that the full effect of the heat is exerted on all sides, completely enveloping the crucible.

The form of apparatus is shown in the accompanying figure. (Fig. 11.)

First, as to the lamp: This simple form of blast lamp has been in use in this laboratory for the past seven years, and has proved itself of such general utility as to merit a brief description.

It consists essentially of a Bunsen burner with the blast entering at the usual inlet for the gas, and the gas entering through a side tube attached where the air is ordinarily admitted. The air is discharged through a tip with circular opening 1½ mim. in diameter, and is so adjusted as to come about even with the lower side of the gas inlet tube. A wire gauze is inserted in the tube about two-thirds of the way towards the top. The lamp is especially adapted for use with blast of constant pressure. By adjustment of the air it may be made to burn with a common Bunsen flame. In connection with the



COKING FURNACE

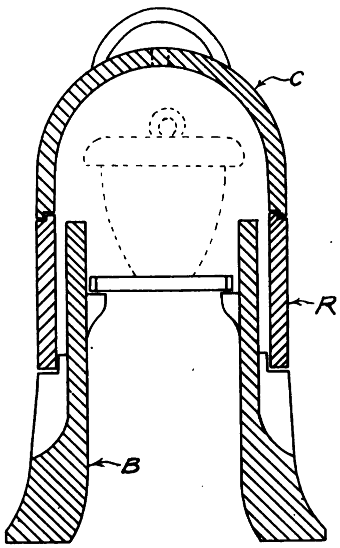
FIGURE 11.

furnace it is allowed to burn for the first 3½ minutes as a strong Bunsen flame of 12 inches when burning free. During the second period of 3½ minutes it burns as a blast lamp. The combustion, however, leaves the tip of the lamp and takes place entirely within the chamber underneath the crucible. In this way an excessive amount of fuel may be forced into a small space by the jet action of the blast. The combustion taking place in this chamber and the hot gases being turned downward to escape through the annular space at the side, a very intense heat is quickly attained.

A cross section is shown through the furnace in figure 12.

The base B rests on a cast plate with an opening 1½ inches in diameter. The crucible rests on a triangular support which permits of the free passage of the gases, part of which may escape through a small opening in the top of C, but mostly they are required to travel downward between the two walls and escape at the lower edge of R.

A common glazed crucible of Royal Berlin Porcelain No. 00 is used. Crucibles as true as possible are selected, with well fitting covers, and these are ground with emery powder until the lid touches



SECTION THRU FURNACE

FIGURE 12.

at all points. Crucibles may be used many times, but if warping occurs the covers may require regrinding—not a difficult matter and easily accomplished by hand in five or ten minutes.

SULPHUR.

We come now to sulphur, a constituent having more importance than is usually ascribed to it; this is especially true of western coals, in which this element varies from 1 per cent to 5 per cent. One of its characteristics, and by no means the least, is the part it plays as a disturbing element in nearly all the determinations in coal analysis. The Eschka method is satisfactory, but heat other than from a gas flame must be used. There is still some question as to the likelihood

of sulphur being left in the residue, and also as to the necessity of dehydrating the silica. The use of sodium peroxide as an oxidizing agent has received considerable attention, but the violence of the reaction has brought disfavor upon the method. However, by means of a closed bomb, as in the Parr calorimeter, there has been fully demonstrated the practicability of using sodium peroxide for this purpose. Indeed some years ago, Mr. Milton Hersey of Montreal, Canada, in a communication to the author reported the very satisfactory use of the residues from the calorimetric process for gravimetrically determining the sulphur. Later articles by Sundstrom* and by von Konek† have advocated the same method.

It is not my purpose now to enter into a discussion of this phase of the matter, but simply to emphasize the fact of the completeness of the oxidation, which has been verified very many times by the writer.

Coupling the sodium peroxide method of arriving at a combustion with the photometric method proposed by Mr. Hinds,‡ there seem to be possibilities well worth investigating. The work with the photometer, however, either as outlined by Mr. Hinds, or as elaborated by Mr. Jackson,§ was not found satisfactory. A careful study was made of the variable elements that entered into the proposition. The method prescribed a candle of standard power, maintained at a definite distance from the bottom of the graduated tube in which was read the depth of liquid through which the outline of the candle flame could be seen. It was soon found that the strength of the light had little to do with the matter. A stronger light would illuminate the liquid to a corresponding degree and cause the outline of the candle flame to disappear at about the same depth as a lesser light with a less illumination of the liquid. As between a common candle and a forty candle power acetylene light there was no marked difference. Indeed, the greatest difference was noted when the diffused light was cut out by diaphragms, in which case the light could be seen through a greater depth. An extreme illustration of this fact was afforded by completely blackening an incandescent light bulb and then cleaning a small spot to show a short length of the glowing filament. This bit of filament, which afforded no illumination to the liquid, could be seen through a very much greater depth than was the case with an ordinary candle, though its power was far below the standard. Other disturbing conditions related to the method of pre-

* Jour. Amer. Chem. Soc., XXV., 184.
† Zeit. fur. Ang. Chem., 1903, p. 517.
‡ Jour. Amer. Chem. Soc., XXIII, 269.
§ Jour. Amer. Chem. Soc. XXIII, 799.

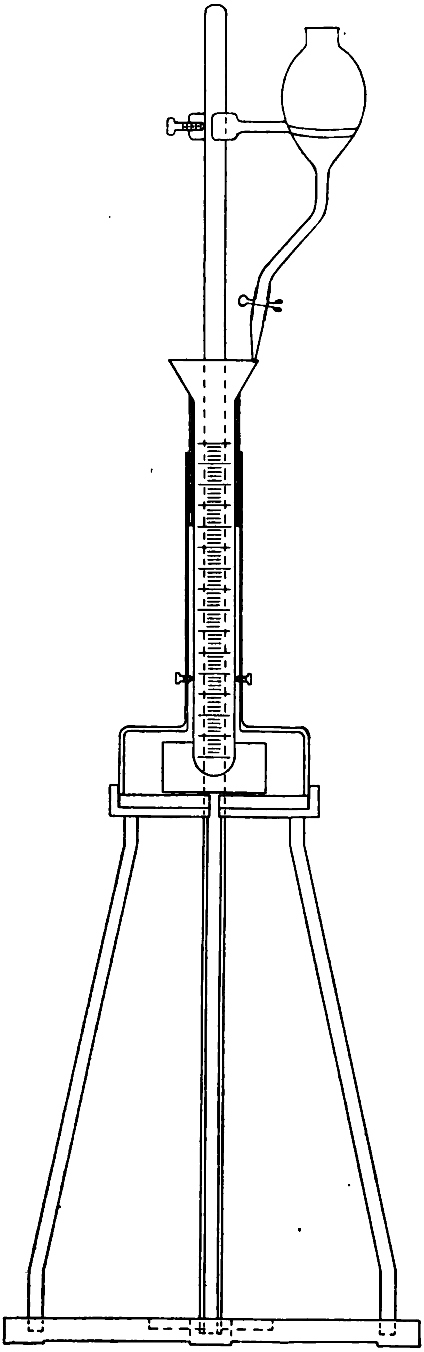


FIG. 13. Photometer for sulphur determinations.

cipitation, whether hot or cold, whether the barium salt was added in the solid or the liquid state, whether readings were made at once. or on standing, or whether precipitations made in the cold were subsequently heated or not. The control of the conditions regarding the light has been accomplished with a greatly modified apparatus in the following manner, as shown in Fig. 13.

The tube graduated in millimeters is placed in a receptacle having a little clear water in the bottom. The flask is placed on a square of glass resting on a carbon plate about $\frac{5}{8}$ of an inch thick and having a $\frac{1}{4}$ inch hole in the center. The plate is adjusted about 8 inches above the flame of a common candle. It will be noticed that the reading tube has a round bottom. This is carefully blown, of clear glass without flaw, and ground on the outer surface; the whole when immersed playing the part of a lens. By this arrangement, together with the diaphragm effect of the hole in the carbon plate, a pencil of light is secured with the minimum amount of illumination being imparted to the liquid. Moreover, instead of the varying and indefinite outline of a candle flame there appears a steady compact point of light. The end reading is thereby rendered sharp and definite. It is interesting to note that precipitations made with the barium salt in solution, or with the sulphate solution hot, transmit the rays from the candle as white light, while in the case of precipitations made with the crystals of the salt, the red rays only are transmitted, the illumination of the liquid is in this way still further reduced, and the sharpness of the end reading is thereby promoted. To secure concordant results, definiteness of precipitation must be obtained. This is accomplished by adding the barium salt to the 100 cc. of solution at room temperature, and after dissolving completely, heat on the water bath to about 70°. Let stand for half an hour and bring to the room temperature, when it is ready to transfer to the photometric tube for reading. With this device it has been necessary to work out a new table. (Table XI.) The conditions are purely empirical, but not arbitrary within reasonable limits, except as to the size of the hole through the plate and the method of precipitation. The table has been developed directly from a standard solution of potassium sulphate having 0.5438 grains dissolved in a litre, thus containing 0.0001 grams of sulphur by weight per cubic centimeter of solution.

With this form of apparatus, the facility with which the sulphur determinations may be made has enabled us to undertake an additional factor in the case of each sample, viz., the estimation of the

amount of sulphur remaining in the coke after the volatile matter has been driven off. The coke is pulverized and burned with sodium peroxide in the calorimeter bomb as usual, and the sulphur deter-

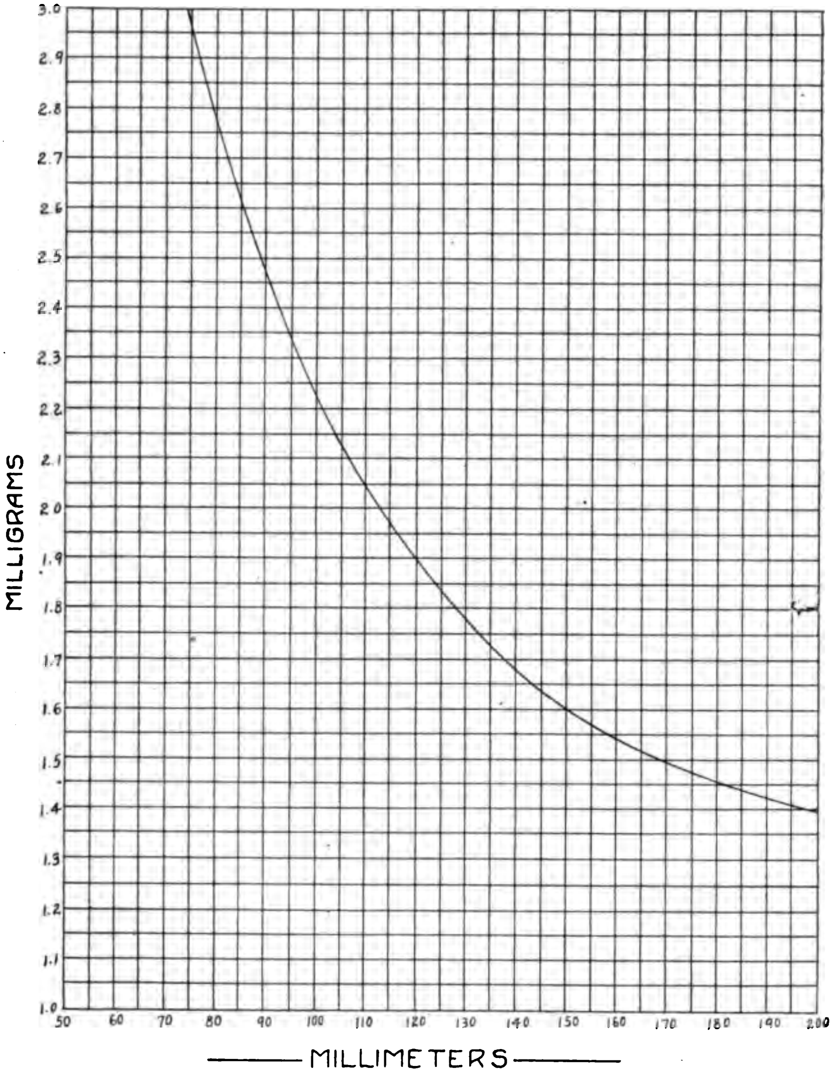


PLATE VI—CURVE FOR SULPHUR READINGS

mined in the residue by means of the photometer. Having determined the total sulphur in the coal, the difference between these two factors represents the volatile sulphur. In the analytical tables at the end these divisions are observed throughout.

Results from use of this method as above outlined, in comparison with those obtained under standard conditions, are shown in Table XI.

TABLE XI.

Showing Percentages of Sulphur.

Illinois Coal.	Washings from Mahler Bomb. (Per cent.)	Residues from Parr Calorimeter in Photometer. (Per cent.)
1. Odin, pea	2.30	2.17
2. St. John's, lump	1.55	1.65
3. Pana, slack	4.03	4.04
4. Danville, lump	2.16	2.31
5. Ridgely, pea	4.00	4.01
6. Bloomington, lump	2.57	2.68
7. Spring Valley, washed	3.04	3.20
8. Elmwood	1.53	1.61

CALORIFIC VALUES.

1st. By calculation: Many attempts have been made to develop a reliable formula for calculating heat values from analytical data. The formula of Dulong is the most reliable and is recommended by the committee of the American Chemical Society in the following form, $8080C + 34460\,(H - \frac{O}{8}) + 2250S$.* The variations between the observed calorific values and the calculated values as shown in Mahler's tables† range from + 3 per cent to — 3 per cent, though the averages of numerous results are much closer.

The variations in the work of Lord and Haas above referred to are not so great, ranging from + 2 per cent to — 1.8 per cent. Kent‡ has used the factors 3 and 5 times the available hydrogen derived from ultimate analysis to indicate (when subtracted from the total carbon) the amount of fixed carbon, and to the various percentages of fixed carbon he has assigned certain calorific values. His results while interesting seem to show greater conformity in the case of eastern than of western coals.

Possibly quite as good as any method of calculation would be the one already partially suggested in the discussion concerning the derivation of the factor for available hydrogen by means of the curve. The results in the one hundred samples listed in table VI, compare favorably with the hydrogen from ultimate analysis. Indeed, there are some reasons for giving the preference to the proposed method of using the curve for obtaining this factor. According to this plan the formula would be modified thus:

$$\text{Cal.} = 8080\,C + 34500\,(H \text{ from curve}) + 2250\,S.$$

* Jour. Amer. Chem. Soc. XXI., 1130.
† Contribution a l'Etude des combustibles. Mahler, 1892.
‡ Trans. Amer. Inst. Min. Eng., XXVII., 948.

Concerning calculations in general, however, it is well to quote Mahler,* who says: "We cannot give a general formula depending strictly on the chemical composition which will give the calorific power of substances so complex and varied;" or Poole, who says:† "If possible, by all means, have a calorimetric test. If not possible use the best analysis available."

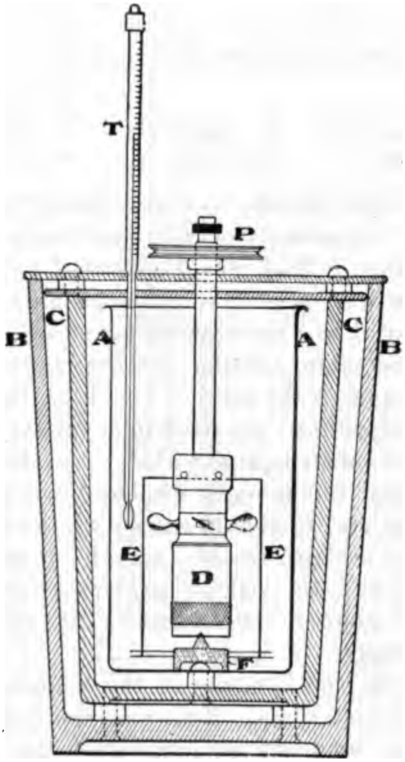


FIGURE 15—PARR CALORIMETER.

2nd. By observation: The calorimeter devised by the writer has met with very general favor and is now widely used both in this country and abroad. It is too well known to call for detailed description here. However, a few modifications and improvements have been made and since it has been used in the accompanying results and also in comparison with quite a list of determinations with the Mahler-Atwater apparatus, a brief reference is here given.

Figure 15 shows the relative positions of parts. The can A.A. for

* As quoted by Poole, The Calorific Power of Fuels, p. 10. † *Ibid.*

the water has a capacity of 2 litres. The insulating vessels B.B. and c.c. are of indurated fibre. The charge of coal and chemical are put in the cartridge D. Upon ignition, the heat generated is imparted to the water and the rise in temperature is indicated on the finely graduated thermometer T. The cartridge or bomb rests on the pivot F and is made to revolve, thus by aid of the small turbine wings attached effecting a complete circulation of the water and equalization of temperature.

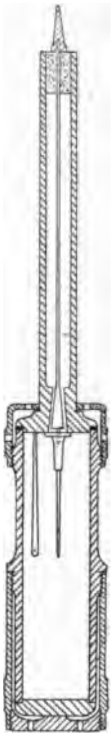
The reaction accompanying the combustion may be represented by the equation:

$$\underset{\text{Sod. perox.}}{56Na_2O_2} + \underset{\text{Coal}}{C_{25}H_{18}O_3} = \underset{\text{Sod. carb.}}{25\ Na_2CO_3} + \underset{\text{Sod hydrate}}{18\ NaOH} + \underset{\text{Sod. oxide}}{22\ Na_2O}$$

With certain substances such as coke, anthracites, petroleums, etc., a more strongly or vigorously oxidizing medium is needed than exists in the peroxide alone. This may be secured by various additions. The most effective are:—a mixture of potassium chlorate and nitrate in the proportion of 1 to 4 and this mixture used in the ratio of 1 to 10 of the sodium peroxide; another effective mixture is an addition of potassium persulphate in the ratio of 1 to 10 of the sodium peroxide. Other substances facilitate the oxidation, notably ammonium salts and certain organic substances, as tartaric or oxalic acid, benzoic acid, etc. In the work on Illinois coals, while ordinarily no extra chemical would be necessary, still in certain cases such as extra slaty coals and coals with excessive volatile matter, and also to guard against variations in the quality of the sodium peroxide, a mixture as first described above, of chlorate and nitrate, has uniformly been used throughout these tests.

One peculiarity in the behavior of the combustion has been improved by the above mixtures. This behavior is probably due to the fact that there is a tendency on the part of the particles of coal in immediate contact with the metal, which is kept cold by exterior contact with the water, to escape action of the chemical. A further improvement in this particular is effected by a modification of the bomb as illustrated in the accompanying figure (Figure 16). The air space about the lower part of the bomb prevents direct contact with the water. However, upon ignition this enclosed air expands and part of it is driven out through the holes below. Later as cooling and contraction occur the water is drawn into the air space and rapid cooling is effected, but the period of high temperature for the interior reaction has been prolonged from a few seconds to a half minute or more.

Other advantages are secured, notably the avoidance of screw threads on the interior or other opportunity for material to lodge and cause sticking or difficult removal of the ends.



CALORIMETER BOMB

FIGURE 16.

TABLE XII.

Comparison of Calorific Factors.

No.	Illinois Coal.	Mahler—Atwater Bomb Calorimeter.	Parr—Per-oxide Calorimeter.	Calculation—8080 C + 34500 "H" + 2250 S.
A	Bloomington, lump	6566	6530	6663
B	Carterville, washed	7174	7185	7061
C	Danville, lump	6797	6762	6742
D	Elmwood, lump	7050	6990	7025
E	Moweaqua, lump	6152	6135	6190
F	Odin, pea	6227	6257	6266
G	Pana, slack	5383	5387	5561
H	Ridgeley, pea	5922	5964	6160
I	St. John, lump	6917	6911	6744
J	Spring Valley, washed	6150	6109	6239

In Table 12 are given results with this apparatus in comparison with the readings obtained by use of a Mahler-Atwater apparatus.

In the third column as already indicated under "Calorimetric Values by Calculation" are given results obtained by use of the formula $8080\ C + 34500\ (H) + 2250\ S$ in which "H" is the percentage of available hydrogen as indicated by the curve in Fig. 8. The values are given in calories per kilo. (Cal. per kilo $\times$ 1.8 = B.T.U. per pound).

The ultimate analyses which have served as the basis for some of the preceding calculations are embodied in Table VIII. There is also included the proximate analyses and a comparison of values btained by the old and new methods. Results are given throughout in per cent.

TABLE XIII.

No.	Illinois Coal.	Proximate Analysis.					Ultimate Analysis.					Combustible— C + (H − ⅛ O)	Combustible— C + (H by curve)
		Ash	Moisture	Volatile matter	Fixed carbon	Total carbon by volume	Total carbon by combustion	Hydrogen	Nitrogen	Oxygen	Sulphur		
A	Bloomington, lump	11.55	3.75	40.15	44.55	64.90	65.48	4.91	1.09	10.75	2.47	69.07	69.10
B	Carterville, w'd, No. 2	5.43	4.87	34.69	55.01	69.90	70.74	5.18	1.04	11.88	0.86	74.44	74.59
C	Danville, lump	3.63	7.51	40.37	48.49	66.69	67.34	5.70	0.76	13.06	2.00	71.41	70.98
D	Elmwood, 3rd vein	6.59	2.91	41.24	49.26	69.81	70.49	5.98	0.66	11.89	1.48	74.94	74.25
E	Moweaqua, lump	9.84	7.36	36.38	46.42	61.25	61.43	4.84	1.14	12.34	3.03	64.48	64.79
F	Odin, pea	12.99	4.36	35.45	47.20	61.92	62.38	5.14	1.14	11.78	2.21	66.05	65.79
G	Pana, slack	16.76	7.61	35.86	39.77	54.80	55.10	4.66	0.91	11.22	3.74	58.36	58.09
H	Ridgeley, pea	13.22	4.72	39.59	42.47	59.89	60.01	5.25	1.28	11.70	3.82	63.80	63.27
I	St. John, lump	4.28	6.33	37.47	50.92	67.19	67.34	5.60	1.24	13.75	1.46	71.22	71.02
J	Spring Valley, wash'd	11.99	5.54	39.33	43.14	61.46	61.91	5.32	1.17	11.19	2.88	65.83	65.28

The samples for Tables XIV and XV were collected between Feb. 8th and June 8th, 1904. These were obtained at the mines from the surface of car lots as made ready for shipment to the consumer. Amounts varying from 40 to 50 pounds were taken and shipped in sacks to the laboratory. In general one sample of lump or screened nut and one of screenings or slack was procured from each mine. The term "slack" has been uniformly applied where the material included all that passed through a 1¼ inch screen.

Immediately upon receipt of the material it was reduced by quartering in the usual manner. A check sample, buckwheat size, was taken, another part was ground to pass through a 100 mesh sieve and each was sealed in a "lightning" fruit jar. The analytical results are given in per cent. The calorific values are given in British thermal units per pound of actual coal as represented by the samples and also in calories per kilo of actual coal.

In Table XIV the results are given first with reference to the air dry condition, it being impossible, owing to the method of transmission, to determine the factor for water lost on air-drying, and thus calculate to the wet coal condition. On the right-hand page, the results are calculated first to the dry (oven dry) condition; and second, to the pure coal (ash and water free) state.

Table XV has been arranged from Table XIV, giving the results as logically resulting from our discussion as to the desirability of expressing the volatile matter under two headings. viz.: the Inert Volatile Matter and the Volatile Combustible, this latter term having its true meaning and not including anything but material actually capable of burning.

TABLE

Number	Source of Sample. County.	Source of Sample. Town.	Source of Sample. Operator.	Description. Size	Description. Seam	Air Dry. Moisture	Air Dry. Ash	Air Dry. Volatile matter	Air Dry. Fixed carbon
1	Bureau	Ladd	Illinois Third Vein C. Co.	W. nut	2	7.04	8.99	38.30	45.67
2	Bureau	do	do	W. slk.	2	6.60	8.04	38.61	46.75
3	Christian	Assumption	Assumption C. & M. Co.	Nut	1	8.46	5.08	38.30	48.16
4	Christian	do	do	Slack	1	7.74	12.72	36.26	43.28
5	Christian	Pana	Penwell Coal Co	Lump	6	9.00	8.36	41.42	41.28
6	Christian	do	Pana Coal Co	Slack	6	8.06	18.66	35.84	37.44
7	Christian	do	do	Lump	6	7.80	8.74	43.72	39.74
8	Clinton	Breese	Breese Coal & M. Co	Slack	6	8.10	14.24	34.00	43.66
9	Clinton	do	do	Nut	6	8.83	8.97	35.24	46.96
10	Clinton	Buxton	Buxton Coal & M. Co	Lump	6	7.95	9.15	36 69	46.21
11	Clinton	Trenton	Trenton Coal Co	Nut	7	8.76	20.19	28.00	43.05
12	Clinton	do	do	Slack	7	9.47	15.28	29.98	45.27
13	Fulton	Astoria	Scripp's Coal Co	Lump	5	7.94	8.64	36.75	46.67
14	Fulton	do	do	Slack	5	9.34	19.96	34.46	36.24
15	Fulton	Canton	Canton-Union Coal Co	Lump	5	11.10	14.36	35.98	38.56
16	Fulton	do	do	Nut	5	10.00	9.88	38.72	41.40
17	Fulton	Cuba	East Cuba Coal Co	Slack	5	7.70	9.77	39.19	43.34
18	Fulton	do	do	Lump	5	9.22	11.14	38.26	41.38
19	Fulton	do	Applegate & Lewis	do	5	7.55	10.18	41 01	43.26
20	Fulton	do	do	Slack	5	7.28	15.68	36.33	40.71
21	Fulton	Farmington	Farmington Coal Co	Lump	5	10.2[illegible]	12.21	35.75	41.79
22	Fulton	do	do	Slack	5	9.62	20.18	33.04	37.16
23	Fulton	Norris	Norris Coal Mining Co	Lump	5	11.78	14.18	33.20	40.84
24	Fulton	do	do	Slack	5	9.44	19.70	33.68	37.18
25	Grundy	Braceville	Braceville Coal Co	do	2	9.70	31.18	26.88	32.24
26	Grundy	do	do	Lump	2	11.86	4.02	37.32	46.80
27	Grundy	S. Wilmington	Chicago, W. & V. C. Co	Slack	2	7.80	29.35	28.84	34.01
28	Grundy	do	do	Lump	2	11.44	5.36	37.09	46 11
29	Henry	Kewanee	Kewanee Coal & M. Co	Nut	6	10.16	6.64	37.33	45.87
30	Henry	do	do	Slack	6	9.99	7.03	37.99	44 99
31	Jackson	Murphysboro	Schmidgall Coal Co	Lump	1	4.96	4.39	34.62	56.03
32	Jackson	do	do	do	1	6.21	4.72	34.29	54.78
33	Knox	Etherly	Etherly Coal Co	do	6	12.74	7.86	36.66	42.74
34	Knox	do	do	Slack	6	10.16	25.00	31.19	33.65
35	LaSalle	Kangley	Star Coal Co	Lump	7	7.68	8.50	38.94	44.88
36	LaSalle	do	do	Slack	7	5.81	22 60	33 05	38.54
37	LaSalle	LaSalle	LaSalle Co. Carbon C. Co.	Lump	2	7.54	5 10	45.30	42.06
38	LaSalle	do	do	Slack	2	7.87	14 20	38.91	39.02
39	LaSalle	do	do	Pea	2	7.56	8.08	41.78	42.58
40	LaSalle	Oglesby	Oglesby Coal Co	Egg	2	10.28	4 09	42.03	43.60
41	LaSalle	do	do	Slack	2	8.28	17.54	35.92	38.26
42	LaSalle	Streator	Chicago, W. & V. C. Co	do	2	8.47	11.98	36.03	43.52
43	LaSalle	do	do	Lump	2	7.96	6.35	39.84	45.85
44	LaSalle	do	Acme Coal Co	Slack	7	6.88	9.57	38 74	44.81
45	LaSalle	do	do	Lump	7	5.52	5.40	42.10	46.98
46	Livingston	Cardiff	Cardiff Coal Co	do	2	11.28	4.84	39.36	44.52
47	Livingston	do	do	Slack	2	10.26	12.02	36.54	41.18
48	Livingston	Fairbury	Walton Bros	do	5	5.30	21.50	33 76	39.44
49	Livingston	do	do	Lump	5	6.57	10.69	39.07	43.67
50	Logan	Lincoln	Citizens' Coal Co	do	5	10.64	15.00	36.78	37.58
51	Logan	do	do	Nut	5	10.44	8.58	38.88	42.10
52	Logan	Mt. Pulaski	Home Coal Co	Lump	5	11.98	12.10	33.64	42.28
53	McLean	Bloomington	McLean County Coal Co	Slack	2	6.77	23.55	34.05	35.63
54	McLean	do	do	Lump	2	7.56	11.78	40.06	40.60
55	McLean	do	do	Slack	3	5.64	16.46	38.06	39.84
56	McLean	do	do	Lump	3	6.98	5.12	44.06	43.84
57	Macon	Decatur	Decatur Coal Co	do	5	8.46	8 01	38.56	44.97
58	Macon	Niantic	do	Nut	5	10.38	9.14	36.47	44.01
59	Macon	do	do	Slack	5	11.01	15.16	34.51	39.32
60	Macoupin	Green Ridge	Green Ridge Coal Co	Lump	6	10.24	5.30	39 96	44.50
61	Macoupin	do	do	Slack	6	8.38	21.14	32.98	37.50
62	Macoupin	Mt. Olive	Consol. C. C. of St. Louis.	Lump	6	9.30	4.53	42.39	43.78
63	Macoupin	do	do	Slack	6	9.62	14.55	34.21	41.62
64	Macoupin	Virden	Chicago-Virden Coal Co	Nut	6	10.27	8.08	38.25	43.40
65	Macoupin	do	do	Slack	6	10.21	9 87	37.60	42.32
66	Madison	Collinsville	Consol. C. C. of St. Louis.	Nut	6	8.26	11.06	38.34	42.34
67	Madison	do	do	Pea	6	7.74	17.68	35.91	38.37

XIV.

Coal.				Oven Dry Coal.							Pure Coal.					Number
Pure coal	Sulphur	Heat units. British thermal units.	Heat units. Calories	Ash	Volatile matter.	Fixed carbon	Pure coal	Sulphur	Heat units. British thermal units.	Heat units. Calories	Volatile matter.	Fixed carbon	Sulphur	Heat units. British thermal units.	Heat units. Calories	
83.97	2.10	11,385	6325	9.67	41.20	49.13	90.33	2.26	12,333	6963	45.60	54.40	2.60	13,577	7532	1
85.36	2.70	11,774	6541	8.61	41.34	50.05	91.39	2.89	12,605	7003	45.24	54.76	3.16	13,793	7663	2
86.46	1.58	12,577	6986	5.55	41.84	52.61	94.45	1.73	13,739	7632	44.30	55.70	1.83	14,542	8079	3
79.54	2.60	11,644	6469	13.80	39.30	46.90	86.20	2.82	12,621	7012	45.59	54.41	3.27	14,641	8134	4
82.70	3.20	11,666	6481	9.12	45.51	45.37	90.88	3.52	12,818	7121	50.08	49.92	3.87	14,104	7836	5
73.28	3.45	10,035	5575	20.30	38.98	40.72	79.70	3.75	10,913	6063	48.91	51.09	4.70	13,694	7608	6
83.46	2.96	11,896	6609	9.48	47.41	43.11	90.52	3.21	12,902	7168	52.38	47.62	3.54	14,254	7919	7
77.66	3.40	11,194	6219	15.49	37.00	47.51	84.51	3.70	12,181	6767	43.78	56.22	4.38	14,416	8009	8
82.20	3.17	11,516	6398	9.84	38.65	51.51	90.16	3.47	12,631	7018	42.88	57.12	3.86	14,011	7784	9
82.90	3.24	11,761	6534	9.94	39.86	50.20	90.06	3.52	12,776	7083	44.26	55.74	3.91	14,185	7881	10
71.05	1.32	10,096	5594	22.13	30.69	47.18	77.87	1.45	11,038	6132	39.41	60.59	1.85	14,173	7874	11
75.25	1.12	10,294	5718	16.87	33.12	50.01	83.13	1.24	11,370	6317	39.84	60.16	1.48	13,663	7591	12
83.42	2.18	11,925	6625	9.39	39.92	50.69	90.61	2.37	12,943	7196	44.05	55.05	2.61	14,294	7941	13
70.70	3.50	10,231	5684	22.02	38.01	39.97	77.98	3.86	11,285	6270	48.74	51.26	4.95	14,470	8039	14
74.54	3.67	10,861	6034	16.15	40.47	43.38	83.85	4.13	12,217	6787	48.27	51.73	4.92	14,572	8096	15
80.12	2.67	11,543	6413	10.98	43.02	46.00	89.02	2.97	12,825	7125	48.33	51.67	3.41	14,405	8003	16
82.53	3.10	12,031	6684	10.59	42.46	46.95	89.41	3.35	13,034	7241	47.48	52.52	3.75	14,576	8098	17
79.64	1.50	11,458	6366	12.27	42.14	45.59	87.73	1.65	12,621	7012	48.04	51.96	1.88	14,387	7993	18
84.27	2.22	12,189	6772	10.78	43.42	45.80	89.22	2.35	12,905	7160	48.66	51.34	2.64	14,466	8037	19
77.04	3.35	11,115	6175	16.91	39.18	43.91	83.09	3.61	11,988	6644	47.15	52.85	4.35	14,427	8015	20
77.54	1.97	11,216	6231	13.59	39.88	46.53	86.41	2.19	12,137	6942	46.10	53.90	2.54	14,463	8035	21
70.20	3.02	10,153	5641	22.33	36.46	41.21	77.67	3.34	11,233	6241	47.06	52.94	4.30	14,464	8036	22
74.04	1.93	10,381	5856	16.07	37.64	46.29	83.93	2.19	11,950	6639	44.84	55.16	2.60	14,238	7910	23
70.86	1.98	10,305	5725	21.75	37.19	41.06	78.25	2.18	11,378	6321	47.52	52.48	2.79	14,540	8078	24
59.12	3.55	8,645	4803	34.53	29.76	35.71	65.47	3.93	9,574	5399	45.46	54.54	6.00	14,623	8124	25
84.12	2.18	12,161	6756	4.56	42.34	53.10	95.44	2.47	13,797	7665	44.37	55.63	5.56	14,455	8031	26
62.85	3.98	9,079	5044	31.84	31.27	36.89	68.16	4.31	9,842	5469	45.88	54.12	6.33	14,443	8024	27
83.20	2.10	11,983	6663	6.06	41.88	52.06	93.94	2.37	13,541	7523	44.58	55.42	2.51	14,412	8007	28
83.20	2.50	11,284	6269	7.39	41.55	51.06	92.61	2.78	12,359	6977	44.86	55.14	3.00	13,561	7534	29
82.98	2.57	11,272	6262	7.81	42.20	49.99	92.19	2.85	12,526	6959	45.79	54.21	3.09	13,584	7547	30
90.65	.62	13,285	7380	4.62	36.43	58.95	95.38	.65	13,977	7765	38.20	61.80	.68	14,653	8141	31
89.07	.62	13,083	7216	5.03	36.56	58.41	94.97	.66	13,827	7693	38.50	61.50	.69	14,580	8100	32
79.40	1.56	11,183	6213	9.00	42.00	49.00	91.00	1.78	12,815	7121	46.17	53.83	1.96	14,085	7825	33
64.84	2.48	9,180	5100	27.82	34.73	37.45	72.18	2.68	10,218	5667	48.10	51.90	3.82	14,157	7865	34
83.82	3.24	12,240	6800	9.20	42.18	48.62	90.80	3.51	13,262	7368	48.69	51.31	1.36	12,535	6964	35
71.59	4.96	10,490	5828	23.99	35.09	40.92	76.01	5.27	11,142	6190	46.16	53.84	6.92	14,653	8141	36
87.36	3.04	12,460	6922	5.51	49.00	45.49	94.49	3.28	13,477	7487	51.84	48.16	3.48	14,261	7923	37
77.93	3.35	10,890	6050	15.42	42.23	42.35	84.58	3.64	11,808	6560	49.92	50.08	4.30	13,973	7763	38
84.36	3.92	12,060	6700	8.73	45.20	46.07	91.27	4.22	13,050	7250	49.52	50.48	4.64	14,293	7941	39
85.63	2.62	11,830	6572	4.55	46.85	48.60	95.45	2.92	13,183	7324	49.08	50.92	3.06	13,811	7673	40
74.18	4.66	10,321	5734	19.12	39.16	41.72	80.88	5.08	11,254	6252	48.43	51.57	6.28	13,914	7730	41
79.55	4.30	11,417	6343	13.09	39.37	47.54	86.91	4.69	12,472	6929	45.29	54.71	5.40	14,349	7978	42
85.69	3.38	12,515	6953	6.89	43.29	49.82	93.11	3.67	13,597	7554	46.49	53.51	3.94	14,603	8113	43
83.55	3.66	12,195	6775	10.27	41.62	48.11	89.72	3.93	13,096	7276	46.36	53.64	4.38	14,598	8110	44
89.08	3.07	13,061	7256	5.71	44.56	49.73	94.29	3.25	13,822	7679	47.26	52.74	3.44	14,661	8145	45
83.88	2.41	11,801	6556	5.45	44.38	50.17	94.55	2.72	13,301	7389	46.92	53.08	2.87	14,070	7817	46
77.72	2.96	10,816	6009	13.39	40.72	45.89	86.61	3.29	12,052	6696	47.01	52.99	3.80	13,917	7732	47
73.20	4.36	10,294	5718	22.69	35.67	41.64	77.31	4.61	10,870	6034	46.12	53.88	5.95	14,059	7811	48
82.74	2.20	12,145	6747	11.44	41.82	46.74	88.56	2.35	12,999	7223	47.22	52.78	2.65	14,677	8154	49
74.36	3.17	10,867	6038	16.78	41.16	42.06	83.22	3.55	12,160	6756	49.46	50.54	4.26	14,614	8119	50
80.98	2.44	10,969	6094	9.57	43.41	47.02	90.43	2.72	12,247	6804	48.01	41.99	3.01	13,546	7526	51
75.92	2.73	10,834	6019	13.74	38.22	48.04	86.26	3.10	12,306	6037	44.31	55.69	3.59	14,207	7928	52
69.68	4.14	10,147	5637	25.26	36.52	38.22	74.74	4.44	10,884	6046	48.86	51.14	5.94	14,560	8089	53
80.66	3.14	11,721	6512	12.75	43.33	43.92	87.25	3.40	12,680	7046	49.67	50.33	3.89	14,533	8074	54
77.90	3.10	11,388	6327	17.44	40.34	42.22	82.56	3.29	12,069	6705	48.85	51.15	3.98	14,617	8121	55
87.90	2.48	12,791	7106	5.50	47.37	47.13	94.50	2.67	13,751	7639	50.14	49.86	2.82	14,553	8085	56
83.53	2.13	11,227	6238	8.75	42.12	49.13	91.25	2.32	12,264	6912	46.16	53.84	2.55	13,442	7468	57
80.48	3.27	10,805	6003	10.19	40.70	49.11	89.81	3.65	12,055	6697	45.32	54.68	4.06	13,426	7459	58
73.83	3.35	9,945	5525	17.04	38.78	44.18	82.96	3.76	11,174	6208	46.74	53.26	4.53	13,469	7483	59
84.46	1.98	12,190	6772	5.90	44.52	49.58	94.10	2.21	13,583	7546	47.31	52.69	2.34	14,434	8019	60
70.48	3.00	10,069	5594	23.07	36.00	40.93	76.93	3.27	10,991	6106	46.80	53.20	4.25	14,286	7937	61
86.17	3.80	11,851	6584	4.99	46.74	48.27	95.01	4.19	13,064	7258	49.19	50.81	4.41	13,752	7640	62
75.83	3.86	10,334	5741	16.10	37.85	46.05	83.90	4.27	11,434	6352	45.11	54.89	5.08	3,626	7570	63
81.65	1.50	11,509	6394	9.01	42.63	48.36	90.99	1.67	12,825	7125	46.85	53.15	1.83	14,095	7831	64
79.92	2.80	10,940	6078	11.00	41.87	47.13	89.00	3.12	12,184	6799	47.04	52.96	3.50	13,689	7605	65
80.68	3.09	11,745	6525	12.06	41.79	46.15	87.94	3.36	12,802	7112	47.52	52.48	3.83	14,556	8087	66
74.58	4.08	10,555	5875	19.17	38.92	41.91	80.83	4.42	11,440	6368	48.15	51.85	5.47	14,178	7877	67

Table XIV—

Number	Source of Sample.			Description.		Air Dry			
	County.	Town.	Operator.	Size	Seam	Moisture	Ash	Volatile matter.	Fixed carbon.
68	Madison	Donkville	Donk Bros. Coal & C. Co	W. nut	6	8.08	7.40	39.86	44.66
69	Madison	do	do	W. pea	6	4.87	8.77	40.83	45.53
70	Madison	Edwardsville	Henrietta Coal Co	Nut	6	7.75	14.40	36.93	40.91
71	Madison	do	do	Slack	6	8.54	15.76	36.37	39.33
72	Marion	Centralia	Pittenger & Davis M. & M. C.	do	6	6.75	18.36	34.13	40.76
73	Marion	do	do	Nut	6	5.43	12.41	38.17	43.99
74	Marion	Odin	Odin Coal Co	do	6	8.52	9.82	37.11	44.55
75	Marion	do	do	Slack	6	6.92	15.95	36.16	40.97
76	Marion	Sandoval	Sandoval Coal & M. Co	Lump	6	5.51	11.94	36.81	45.74
77	Marshall	Wenona	Wenona Coal Co	do	2	10.94	2.32	36.59	50.15
78	Marshall	do	do	Slack	2	10.31	13.14	33.49	43.06
79	Menard	Athens	Wabash Coal Co	Lump	5	9.32	9.04	39.32	42.32
80	Menard	do	do	Slack	5	10.10	16.62	34.82	38.46
81	Menard	Greenview	Greenview C. & M. Co	Lump	5	9.46	8.11	37.62	44.81
82	Menard	do	do	Slack	5	9.58	14.26	36.28	39.88
83	Menard	Middletown	Middletown Coal Co	Lump	5	10.04	9.90	36.89	43.17
84	Menard	do	do	Slack	5	10.37	19.20	33.12	37.31
85	Mercer	Cable	Coal Valley Mining Co	Lump	1	9.02	10.86	39.34	40.78
86	Mercer	do	do	Slack	1	9.02	11.78	37.77	41.43
87	Mercer	Sherrard	do	Lump	1	9.60	8.82	39.36	42.22
88	Mercer	do	do	Slack	1	7.84	18.39	36.72	37.05
89	Montgomery	Litchfield	Litchfield M. & Power Co	do	2	7.94	13.84	36.34	41.88
90	Montgomery	do	do	Lump	2	9.22	5.96	38.74	46.08
91	Peoria	Holles	Third Vein Coal Co	do	2	7.86	7.68	42.66	41.80
92	Peoria	do	do	Nut	2	8.04	7.80	41.13	43.03
93	Perry	DuQuoin	Lake Superior Coal Mines	do	6	8.44	6.52	35.97	49.07
94	Perry	do	do	do	6	7.24	10.04	38.72	44.00
95	Perry	Pinckneyville	White Walnut Coal Co	Lump	6	7.54	7.30	39.20	45.96
96	Perry	do	do	Slack	6	7.26	22.22	31.36	39.16
97	Randolph	Sparta	Boyd Coal & Coke Co	Lump	5	7.44	8.64	37.64	46.28
98	Randolph	do	do	Nut	5	7.09	8.93	36.75	47.23
99	Randolph	Tilden	Crystal Coal Co	Slack	6	7.17	13.15	34.70	44.98
100	Randolph	do	do	Lump	6	8.68	7.73	37.06	46.53
101	St. Clair	French Village	St. Louis & O'Fallon C. Co	do	6	8.08	8.38	41.30	42.24
102	St. Clair	do	do	Slack	6	8.12	16.21	35.44	40.23
103	St. Clair	Marissa	D. Zihlsdorf	Lump	6	7.78	7.34	40.78	44.10
104	St. Clair	do	do	Slack	6	7.15	13.77	37.87	41.21
105	Saline	Eldorado	Eldorado Coal & Coke Co	Lump	5	5.68	8.90	33.32	52.10
106	Saline	do	do	Slack	5	4.36	23.58	29.36	42.70
107	Saline	do	do	do	5	5.04	10.88	34.36	49.72
108	Saline	do	do	do	5	4.00	20.88	30.78	44.34
109	Saline	Harrisburg	Harrisburg M. & C. Co	Lump	5	4.20	5.50	37.12	53.18
110	Saline	do	do	do	5	3.76	7.01	36.11	53.12
111	Saline	do	do	Slack	5	3.70	15.80	33.14	47.36
112	Saline	do	Diamond Coal Co	Lump	5	4.10	6.76	37.17	51.97
113	Saline	do	do	Slack	5	4.72	14.28	32.72	48.28
114	Sangamon	Auburn	Auburn & Alton Coal Co	Lump	6	10.46	7.67	38.96	42.91
115	Sangamon	do	do	Slack	6	9.38	16.37	34.50	39.75
116	Sangamon	do	Chicago-Virden Coal Co	Nut	6	10.42	6.46	39.52	43.60
117	Sangamon	do	do	Slack	6	10.10	14.12	35.78	40.00
118	Sangamon	Cantrall	Cantrall Co-op. Coal Co	Nut	5	10.02	8.22	38.31	43.45
119	Sangamon	do	do	Slack	5	9.64	12.64	36.94	40.78
120	Sangamon	Dawson	Wabash Coal Co	Nut	5	12.56	9.93	34.10	43.41
121	Sangamon	do	do	Slack	5	11.44	16.94	29.18	42.44
122	Sangamon	Riverton	Springfield C. M. Co	do	5	3.38	16.46	36.96	43.20
123	Sangamon	Springfield	Chicago-Springfield C. Co	Lump	5	4.74	11.34	36.64	47.28
124	Sangamon	do	Jones & Adams Co	do	5	11.32	12.96	37.08	38.64
125	Sangamon	do	do	Slack	5	11.56	12.16	34.54	41.74
126	Shelby	Moweaqua	Moweaqua C., M. & M. Co	Nut	5	8.07	10.78	37.14	44.01
127	Shelby	do	do	Slack	5	9.19	10.16	36.82	43.83
128	Vermilion	Catlin	Jones & Adams Co	Lump	7	10.36	5.71	38.18	45.75
129	Vermilion	do	do	Slack	7	9.90	5.02	40.75	44.33
130	Vermilion	Danville	E. S. Gray	do	7	3.44	13.36	35.06	48.14
131	Vermilion	do	Economy Coal Min. Co	Lump	7	8.38	5.65	45.96	43.01
132	Vermilion	do	do	Slack	7	8.00	19.47	34.83	37.70
133	Vermilion	do	Hoskins Brothers	Lump	6	9.30	7.06	41.84	41.80
134	Vermilion	Fairmount	Consol. C. Co. of St. Louis	Slack	7	7.59	18.69	36.47	37.25

Continued.

COAL.				OVEN DRY COAL.							PURE COAL.					
Pure coal...	Sulpher.....	Heat units. British thermal units.	Heat units. Calories....	Ash......	Volatile matter.	Fixed carbon..	Pure coal.....	Sulphur.....	Hhat units. British thermal units.	Hhat units. Calories....	Volatile matter.	Fixed carbon..	Sulphur.....	Heat units. British thermal units.	Heat units. Calories...	Number........
84.52	3.00	12,004	6669	8.05	43.36	48.59	91.95	3.26	13,006	7255	47.16	52.84	3.55	14,202	7890	68
86.36	2.96	12,364	6869	9.22	42.92	47.86	90.78	3.11	12,997	7220	47.27	52.73	3.42	14,315	7953	69
77.84	4.74	11,002	6112	15.61	40.04	44.35	84.39	5.13	11,927	6626	47.44	52.56	6.08	14,130	7850	70
75.70	4.00	10,879	6044	17.23	39.77	43.00	82.77	4.37	11,894	6608	48.05	51.95	5.28	14,373	7985	71
74.89	4.36	10,836	6019	19.69	36.60	43.71	80.31	4.67	11,620	6946	45.57	54.43	5.82	14,466	8037	72
82.16	3.60	11,658	6477	13.12	40.36	46.52	86.88	3.81	12,327	6849	46.46	53.54	4.38	14,189	7883	73
81.66	3.00	11,138	6188	10.74	40.57	48.69	89.26	3.27	12,175	6764	45.43	54.57	3.67	13,638	7577	74
77.13	3.80	10,766	5981	17.13	38.86	44.01	82.87	4.08	11,565	6425	46.88	53.12	4.92	13,955	7753	75
82.55	2.60	12,020	6678	12.63	38.96	48.41	87.37	2.75	12,722	7069	44.59	55.41	3.14	14,560	8089	76
86.74	.79	12,139	6744	2.61	41.08	56.31	37.39	.89	13,633	7574	42.18	57.82	.91	13,995	7775	77
76.55	2.67	10,969	6094	14.64	37.35	48.01	85.36	2.98	12,231	6795	43.75	56.25	3.48	14,331	7962	78
81.64	4.44	11,503	6391	9.97	43.36	46.67	90.03	4.90	12,685	7048	48.16	51.84	5.44	14,088	7827	79
73.28	4.20	10,288	5716	18.49	38.73	42.78	81.51	4.57	11,444	6358	47.52	52.48	5.73	14,040	7800	80
82.43	2.41	11,550	6528	8.95	41.56	49.49	91.05	2.66	12,756	7210	45.64	54.36	2.92	14,255	7919	81
76.16	3.04	10,727	5959	15.77	40.12	44.11	84.23	3.36	11,846	6581	47.63	52.37	3.99	14,081	7823	82
80.06	2.43	11,290	6272	11.00	41.01	47.99	89.00	2.70	12,349	6972	46.08	53.92	3.03	14,103	7835	83
70.43	3.13	9,799	5444	21.43	36.94	41.63	78.57	3.49	10,933	6074	47.02	52.98	4.44	13,914	7730	84
80.12	3.93	11,453	6363	11.94	43.24	44.82	88.06	4.32	12,588	6993	49.10	50.90	4.90	14,293	7941	85
79.20	4.00	11,380	6322	12.95	41.51	45.54	87.05	4.46	12,508	6949	47.68	52.32	5 05	14,365	7981	86
81.58	3.02	11,875	6547	9.75	43.54	46.71	90.25	3.34	13,036	7242	48.25	51.75	3.70	14,446	8026	87
73.77	4.78	10,141	5634	19.96	39.84	40.20	80.04	5.19	11,005	6114	49.79	50.21	6.48	13,748	7638	88
78.22	3.10	11,143	6191	15.03	39.47	45.50	84.97	3.37	12,119	6733	46.35	53.65	3.96	14,245	7914	89
84.82	1.77	12,100	6722	6.56	42.68	50.76	93.44	1.95	13,327	7404	45.67	54.33	2.09	14,265	7925	90
84.46	2.41	11,880	6600	8.33	46.31	45.36	91.67	2.60	12,895	7164	50.51	49.49	2.85	14,065	7814	91
84.16	3.13	11,914	6619	8.47	44.73	46.80	91.53	3.40	12,955	7197	48.87	51.13	3.72	14,153	7863	92
85.04	1.82	11,953	6640	7.12	39.29	53.59	92.88	1.99	13,054	7252	42.29	57.71	2.14	14,052	7807	93
82.72	3.04	11,790	6550	10.82	41.74	47.44	89.18	3.27	12,710	7061	46.81	53.19	3.67	14,250	7917	94
85.16	1.88	12,082	6713	7.89	42.40	49.71	92.11	2.03	13,070	7261	46.03	53.97	2.20	14,189	7883	95
70.52	3.10	10,001	5556	23.96	33.82	42.22	76.04	3.34	10,784	5991	44.46	55.54	4.39	14,178	7877	96
83.92	2.40	11,790	6550	9.34	40.66	50.00	90 66	2.59	12,735	7075	44.85	55.15	2.86	14,049	7805	97
83.98	3.45	11,840	6578	9.61	39.55	50.84	90.39	3.71	12,744	7080	43.77	56.23	4.10	14,097	7832	98
79.68	3.13	11,430	6350	14.16	37.38	48.46	85.84	3.37	12,119	6733	43.55	56.45	3.93	14,344	7969	99
83.59	3.07	11,525	6403	8.46	40.59	50.95	91.54	3.36	12,619	7011	44.34	55.56	4.62	13,786	7659	100
83.54	3,35	11,549	6416	9.12	44.93	45.95	90.88	3.64	12,565	6981	49.44	50.56	4.01	13,827	7682	101
75.67	4.00	10,514	5841	17.64	38.56	43.80	82.36	4.35	11,445	6358	46.83	53.17	5 28	13,892	7718	102
84.88	3.23	11,684	6491	7.96	44.22	47.82	92.04	3.50	12,670	7039	48.04	51.96	3.80	13,764	7647	103
79.08	3.93	10,919	6066	14.82	40.79	44.39	85.18	4.23	11,763	6535	47.89	52.11	4.97	13,807	7671	104
85.42	1.18	12,668	7038	9.44	35.32	55.24	90,56	1.25	13,430	7461	39.02	60.98	1.38	14,830	8239	105
72.06	2.00	10,400	5778	24.63	30.72	44.65	75.37	2.09	10,875	6041	40.75	59.25	2.77	14,432	8018	106
84.08	4.00	12,179	6766	11.46	36.18	52.36	88.54	4.21	12,821	7125	40.87	59.13	4.75	14,486	8048	107
75.12	3.70	10,924	6069	21.75	32.07	46.18	78.25	3.85	11,379	6323	40.97	59.03	4.92	14,542	8079	108
90.30	1.64	13,303	7391	5.74	38.75	55.51	94.26	1.71	13,889	7716	41.12	58.88	1.81	14,734	8186	109
89.23	1.81	13,151	7306	7.28	37.52	55.20	92.72	1.88	13,666	7592	40.47	59.53	2.03	14,734	8186	110
80.50	2.40	10,586	5881	16.41	34.41	49.18	83.59	2.49	10,991	6106	41.17	58.83	2.98	13,150	7306	111
89.14	1.55	12,949	7194	7.05	58.76	54.19	92.95	1.62	13,502	7501	41.70	58.30	1.74	14,526	8070	112
81.00	2.70	11,351	6306	15.00	34.34	50.66	85.00	2.83	11,911	6617	40.40	59.60	3.33	14,014	7786	113
81.87	2.60	11,660	6478	8.57	43.51	47.92	91 43	2.90	13,022	7246	47.58	52.42	3 17	14,241	7912	114
74.25	3.50	10,514	5841	18.06	38.07	43.87	81.94	3.86	11,602	6446	44.38	55.62	4.71	14,160	7867	115
83.12	2.73	11,438	6350	7.21	44.11	48.68	92.79	3.05	12,759	7089	47.54	52.46	3.28	13,750	7639	116
75.78	3.02	10,636	5909	15.72	39.79	44.49	84.28	3.36	11,831	6573	47.21	52.79	3.99	14,038	7799	117
81.76	1.54	11,536	6409	9.13	42.58	48.29	90.87	1.71	12,821	7123	46.86	53.14	1.88	14,108	7838	118
77.72	3.45	10,929	6072	13.99	40.88	45.13	86.01	3.82	12,095	6720	47.52	52.48	4.43	14,061	7812	119
77.51	2.14	11,104	6169	11.35	39.00	49.65	88.65	2.44	12,698	7055	43.99	56.01	2.76	14,326	7959	120
71.62	3.13	10,024	5569	19.13	32.95	47.92	80.87	3.53	11,318	6288	40.74	59.25	4.37	13,995	7775	121
80.16	4.10	11,419	6344	17.04	38.25	44.71	82.96	4.24	11,819	6566	46.11	53.89	5.11	14,245	7914	122
83.92	2.90	11,975	6653	11.91	38.46	49.63	88.09	3.04	12,371	6984	43.66	56.34	3.45	14,272	7929	123
75.72	3.90	10,670	5928	14.62	41.81	43.57	85.38	4.39	12,033	6685	48.96	51.04	5.15	14,092	7829	124
76.28	4.08	10,805	6003	13.75	39.05	47.20	86.25	4.61	12,216	6787	45.28	54.72	5.34	14,162	7868	125
81.15	3.30	11,176	6209	11.72	40.40	47.88	88.28	3.59	12,157	6754	45.77	54.23	4.06	13,773	7652	126
80.65	3.27	11,261	6256	11.19	40.54	48.27	88.81	3 60	12,307	6837	45.65	54.35	4.05	13 959	7755	127
83.93	1.47	11,836	6631	6.37	42.59	51.04	93.63	1.64	13,204	7399	45.48	54.52	1.75	14,218	7899	128
85.08	2.00	10,350	5750	5.57	45.23	49.20	94.43	2.23	11,487	6382	47.90	52.10	2.35	12,162	6757	129
83.20	3 38	11,909	6612	13.83	36.31	49.86	86.17	3.50	12,333	7883	42.14	57.86	4.06	14,304	7947	130
88.98	2.88	12,589	6994	6.17	46.89	46.94	93.83	3.14	13,740	7633	51.65	48.35	3.23	14,149	7861	131
72.53	3.40	10,603	5891	21.16	37.86	40.98	78.84	3.69	11,525	6403	48.02	51.98	4.68	14,617	8121	132
83.64	2.40	11,385	6325	7.78	46.13	46.09	92.22	2.64	12,552	6974	50.02	49.98	2.87	13,609	7561	133
73.72	3 67	10,289	5716	20.22	39.47	40.31	79.78	3.97	11,133	6185	49.48	50.52	4.97	13,955	7753	134

Table XIV—

Number	Source of Sample.			Description.		Air Dry			
	County.	Town.	Operator.	Size	Seam	Moisture	Ash	Volatile matter	Fixed carbon
135	Vermilion	Grape Creek	Bunting Bros	Lump.	6	11.85	5.90	35.49	46.76
136	Vermilion	do	Kelleyville Coal Co	do	6	11.57	5.14	34.81	48.48
137	Vermilion	S. Westville	Westville Coal Co	do	6	11.20	5.82	35.86	47.12
138	Vermilion	do	do	Slack	6	11.06	7.30	35.34	46.30
139	Will	Braidwood	Murphy, Keenan & Co.	Lump.	2	11.44	4.26	36.28	48.02
140	Will	do	do	Slack	2	10.52	16.38	32.57	40.53
141	Williamson	Bush	Western Coal & Min. Co	Lump.	7	5.90	9.96	35.00	49.14
142	Williamson	do	do	Slack	7	4.92	12.24	35.64	47.20
143	Williamson	Carterville	Carterv. & Big M'dy C. Co.	do	7	6.04	7.62	33.18	53.16
144	Williamson	do	do	Lump.	7	6.32	6.10	32.58	54.99
145	Williamson	Herrin	New Kentucky Coal Co	W. slk.	7	5.00	10.62	31.76	52.62
146	Williamson	do	Chicago & Carterv. C. Co.	W. nut.	7	5.87	6.36	33.53	54.24
147	Williamson	do	do	W. slk.	7	5.46	11.17	30.96	52.41
148	Williamson	do	do	Lump.	7	6.00	5.46	32.32	56.22
149	Williamson	Lauder	Carterv. & Big M'dy C. Co.	Slack	7	6.35	17.80	40.81	35.04
150	Williamson	Carterville	New Ohio Coal Co	W. nut.	7	3.28	8.52	32.00	56.20

Concluded.

Coal.				Oven Dry Coal.							Pure Coal.					
		Heat units.							Heat units.				Heat units.			
Pure coal.....	Sulphur.......	British thermal units..	Calories....	Ash	Volatile matter.	Fixed carbon ..	Pure coal.....	Sulphur.......	British thermal units.	Calories....	Volatile matter.	Fixed carbon ..	Sulphur......	British thermal units.	Calories....	Number ....
82.25	2.43	11,565	6425	6.70	40.24	53.06	93.30	2.76	13,118	7288	43.15	56.85	2.96	14,059	7811	135
83 29	.75	11,660	6478	5.81	39.37	54.82	94.19	.85	13,183	7324	41.80	58.20	.90	14,000	7778	136
82.98	.83	11,824	6569	6.55	40.38	53.07	93.45	.93	13,312	7396	43.22	56.78	1.00	14,248	7916	137
81.64	.84	11,632	6463	8.20	39.74	52.06	91.80	.94	13,080	7267	43.28	56.72	1.02	14,247	7915	138
84.30	1.95	11,300	6278	4.81	40.97	54.22	25.19	2.20	12.760	7089	43.04	56.96	2.32	13,406	7448	139
73.10	2.34	9,675	5375	18.31	36.40	45.29	81.69	2.62	10,812	6007	44.56	55 44	3.20	13,233	7352	140
84.14	1.97	12,072	6736	10.59	37.19	52.22	89.41	2.09	12,829	7187	41.59	58.41	2.34	14,410	8006	141
82.84	1.15	11,863	6591	12.87	37.49	49.64	87.13	1.21	12,477	6932	43.02	56.98	1.38	14,320	7956	142
86.34	1.03	12,611	7006	8.11	35.31	56.58	91.89	1.10	13,421	7456	38.43	61.57	1.19	14,603	8113	143
87.57	1.00	12,706	7059	6.52	34.78	58.70	93.48	1.06	13,563	7535	37.21	62.79	1.14	14,522	8068	144
84.38	2.22	12,325	6847	11.18	33.43	55.39	88.82	2.36	12,974	7208	37.64	62.36	2.63	14,607	8115	145
87.77	.83	12,706	7059	6.75	35.62	57.63	93.25	.88	13,498	7499	38.21	61.79	.95	14,477	8043	146
83.37	1.85	12,145	6747	11.82	32.75	55.43	88.18	1.96	12,845	7136	37.14	62.86	2.22	14,567	8093	147
88.54	.82	12,775	7097	5.81	34.38	59.81	94.19	.87	13,582	7549	36.53	63.47	.93	14,427	8015	148
75.85	1.14	10,508	5838	19.01	43.58	37.41	80.99	1.22	11,819	6233	53.80	46.20	1.50	13,834	7697	149
88.80	.89	12,560	6967	8.81	33.08	58.11	91.19	.92	12,985	7214	36.28	63.72	1.01	14,239	7911	150

TABLE XV.

	Town.	No. table	Moisture	Ash	Inert volatile	Combustible volatile	Fixed carbon	Ratio	Total carbon	Available hydrogen	Sulphur
1	Assumption	3	8.46	5.08	12.02	26.28	48.16	30.3	69.09	3.77	1.58
2	Assumption	4	7.74	12.72	11.30	24.96	43.28	30.5	62.24	3.40	2.60
3	Astoria	13	7.94	8.64	13.66	23.09	46.67	27.2	64.12	3.46	2.18
4	Astoria	14	9.34	19.96	8.94	25.52	36.24	34.3	55.15	3.14	3.50
5	Athens	79	9.32	9.04	11.61	27.71	42.32	31.9	62.15	3.44	4.44
6	Athens	80	10.10	16.62	10.78	24.04	38.46	30.1	55.17	3.13	4.20
7	Auburn	114	10.46	7.67	12.49	26.47	42.91	32.2	63.27	3.51	2.60
8	Auburn	115	9.38	16.37	11.63	22.87	39.75	29.1	56.08	3.04	3.50
9	Auburn	116	10.42	6.46	17.20	22.32	43.60	22.7	59.89	3.30	2.73
10	Auburn	117	10.10	14.12	10.74	25.04	40.00	32.0	58.77	3.25	3.02
11	Bloomington	53	6.77	23.55	8.25	25.80	35.63	34.2	54.21	3.08	4.14
12	Bloomington	54	7.56	11.78	10.20	29.86	40.60	36.2	63.63	3.60	3.14
13	Bloomington	55	5.64	16.46	10.24	27.82	39.84	34.9	61.09	3.47	3.10
14	Bloomington	56	6.98	5.12	11.09	32.97	43.84	37.3	70.17	4.16	2.48
15	Braceville	25	9.70	31.18	8.50	18.38	32.24	27.9	44.67	2.40	3.55
16	Braceville	26	11.86	4.02	10.61	26.71	46.80	30.8	67.62	3.71	2.18
17	Braidwood	139	11.44	4.26	14.86	21.42	48.02	23.4	63.81	3.68	1.95
18	Braidwood	140	10.52	16.38	13.17	18.40	40.53	24.5	53.66	2.93	2.34
19	Breese	8	8.10	14.24	11.48	22.52	43.66	26.7	59.58	3.20	3.40
20	Breese	9	8.83	8.97	13.55	21.69	46.96	24.4	62.08	3.40	3.17
21	Bush	141	5.90	9.96	10.39	24.61	49.14	27.9	68.12	3.66	1.97
22	Bush	142	4.92	12.24	14.84	20.81	47.20	25.4	63.39	3.46	1.15
23	Buxton	10	7.95	9.15	11.89	24.80	46.21	28.1	64.29	3.48	3.24
24	Cable	85	9.02	10.86	9.39	29.45	40.78	35.4	63.17	3.63	3.93
25	Cable	86	9.02	11.78	13.14	24.53	41.43	29.5	58.78	3.18	4.06
26	Canton	15	11.10	14.36	12.54	23.44	38.56	30.2	55.31	3.02	3.67
27	Canton	16	10.00	9.88	13.00	25.72	41.40	32.0	61.04	3.41	2.67
28	Cantrall	118	10.02	8.22	15.58	22.73	43.45	29.1	61.30	3.34	1.54
29	Cantrall	119	9.64	12.64	12.57	24.37	40.78	30.3	58.51	3.19	3.45
30	Cardiff	46	11.28	4.84	11.78	27.58	44.52	32.6	66.03	3.66	2.41
31	Cardiff	47	10.26	12.02	12.08	24.46	41.18	30.7	59.43	3.25	2.96
32	Carterville	143	6.04	7.62	11.79	21.39	53.16	23.8	69.72	3.80	1.03
33	Carterville	143	6.32	6.10	11.89	20.69	54.99	22.4	70.83	3.85	1.00
34	Carterville	150	3.28	8.52	11.66	20.34	56.30	21.6	71.87	3.88	.89
35	Catlin	128	10.36	5.71	11.85	26.33	45.75	31.6	66.91	3.70	1.47
36	Catlin	129	9.90	5.02	13.10	27.65	44.33	33.1	66.27	3.71	2.00
37	Centralia	72	6.75	18.36	10.82	23.31	40.76	28.1	56.66	3.05	4.36
38	Centralia	73	5.43	12.41	12.31	25.86	43.99	30.1	62.85	3.40	3.60
39	Collinsville	66	8.26	11.06	11.88	26.46	42.34	31.9	62.26	3.45	3.09
40	Collinsville	67	7.74	17.68	10.74	25.17	38.67	31.8	56.64	3.12	4.68
41	Cuba	17	7.70	9.77	13.14	26.05	43.34	31.1	62.84	3.45	3.10
42	Cuba	18	9.22	11.14	12.86	25.40	41.38	33.0	61.81	3.47	1.50
43	Cuba	19	5.55	10.18	10.99	30.02	43.26	35.5	67.18	3.88	2.22
44	Cuba	20	7.28	15.68	9.35	26.98	40.71	33.3	60.94	3.40	3.35
45	Danville	130	3.44	13.36	11.06	24.00	48.14	26.2	65.22	3.54	3.38
46	Danville	131	8.38	5.65	15.29	30.67	43.01	35.7	66.94	3.86	2.88
47	Danville	132	8.00	19.47	11.46	23.37	37.70	30.9	54.65	3.02	3.40
48	Danville	133	9.30	7.06	14.81	27.03	41.80	33.5	62.89	3.54	2.40
49	Dawson	120	12.56	9.93	10.11	23.99	43.41	29.9	61.89	3.37	2.14
50	Dawson	121	11.44	16.94	9.67	18.51	42.44	22.4	54.80	3.02	3.13
51	Decatur	57	8.46	8.01	16.05	22.51	44.97	27.4	62.00	3.35	2.13
52	Donkville	68	8.08	7.40	12.70	27.16	44.66	31.5	65.22	3.60	3.00
53	Donkville	69	4.87	8.77	13.88	26.95	45.53	31.0	65.90	3.62	2.96
54	DuQuoin	93	8.44	6.52	14.33	21.64	49.07	25.0	65.35	3.54	1.82
55	DuQuoin	94	7.24	10.04	12.45	26.27	44.00	31.0	63.73	3.50	3.04
56	Edwardsville	70	7.76	14.40	10.44	26.49	40.91	31.2	59.40	3.26	4.74
57	Edwardsville	71	8.54	15.76	10.75	25.62	39.33	31.9	57.75	3.20	4.00
58	Eldorado	105	5.68	8.90	11.19	22.13	52.10	24.8	69.28	3.77	1.18
59	Eldorado	106	4.36	23.58	9.87	24.49	42.70	25.4	66.59	3.62	4.00
60	Eldorado	107	5.04	10.88	10.13	19.23	49.72	25.0	56.86	3.07	2.00
61	Eldorado	108	4.00	20.88	7.93	22.85	44.34	26.3	60.19	3.27	3.70
62	Etherly	33	12.74	7.86	14.46	22.20	42.74	29.0	60.13	3.25	1.56
63	Etherly	34	10.16	25.00	12.10	19.09	33.65	29.5	47.68	2.58	2.48
64	Fairbury	48	5.30	21.50	9.30	24.46	39.44	30.7	56.50	3.04	4.36
65	Fairbury	49	6.57	10.69	10.44	28.63	43.67	34.2	66.33	3.77	2.20
66	Fairmount	134	7.59	18.69	12.04	24.43	37.25	32.3	54.96	3.05	3.67
67	Farmington	21	10.25	12.21	10.34	25.41	41.79	32.4	61.79	3.44	1.97
68	Farmington	22	9.62	20.18	10.60	22.44	37.16	30.7	53.74	2.94	3.02
69	French Village	101	8.08	8.38	13.46	27.84	42.24	33.2	63.20	3.53	3.35

Table XV—Continued.

	Town.	No. table	Moisture	Ash	Inert volatile	Combustible volatile	Fixed carbon	Ratio	Total carbon	Available hydrogen	Sulphur
70	French Village	102	8.12	16.21	12.18	23.26	40.23	28.8	56.46	3.03	4.00
71	Grape Creek	135	11.85	5.90	11.11	24.38	46.76	28.3	65.19	3.52	2.43
72	Grape Creek	136	11.57	5.14	13.27	21.54	48.48	31.6	65.46	3.62	2.41
73	Greenview	81	9.46	8.11	10 94	26.68	44.81	30.9	57.71	3.17	3.04
74	Greenview	82	9.58	14.26	12.24	24.04	39.88	32.1	65.55	3.64	1.98
75	Greenridge	60	10.24	5.30	13.29	26.67	44.50	30.6	53.96	2.95	3.00
76	Greenridge	61	8.38	21.14	10.57	22.41	37.50	27.1	72.97	3.92	1.64
77	Harrisburg	109	4.20	5.50	11.77	25.35	53.18	25.2	70.99	3.87	1.81
78	Harrisburg	110	3.76	7.01	12.56	23.55	53.12	23.5	61.87	3.40	2.40
79	Harrisburg	111	3.70	15.80	12.83	20.31	47.36	27.1	71.25	3.84	1.55
80	Harrisburg	112	4.10	6.76	12.50	24.67	51.97	25.4	64 73	3.50	2.70
81	Harrisburg	113	4.72	14.28	10.07	22.65	48.28	21.6	67.15	3.64	2.22
82	Herrin	145	5.00	10.62	11.37	20.89	52.62	23.4	70.79	3.88	.83
83	Herrin	146	5.87	6.36	12.27	21.26	54.24	21.6	66.89	3.64	1.85
84	Herrin	147	5.46	11.17	10.99	19.97	52.41	21.4	71.53	3.87	.82
85	Herrin	148	6.00	5.46	12.32	20.00	56,22	36.3	65.59	3.80	2.41
86	Holles	91	7.86	7.68	12.66	30.00	41.80	32.3	63.60	3.54	3.13
87	Holles	92	8.04	7.80	13.89	27.24	43.03	31.9	65.90	3.66	3.24
88	Kangley	35	7.68	8.50	11.02	27.92	44.88	28.6	53.99	2.90	4.96
89	Kangley	36	5.81	22.60	9.74	23.31	38.54	28.2	63.88	3.46	2.50
90	Kewanee	29	10.16	6.64	13.36	23.97	45.87	27.9	62.39	3.37	2.57
91	Kewanee	30	9.99	7.03	13.65	24.34	44.99	28.6	64.01	3.45	2.10
92	Ladd	1	7.04	8.99	14.42	23.88	45.67	28.6	65.50	3.53	2.70
93	Ladd	2	6.60	8.04	13.63	24 98	46.75	37.7	67.58	4.02	3.04
94	LaSalle	37	7.54	5.10	12.72	32.58	42.06	34.8	59.85	3.43	3.35
95	LaSalle	38	7.87	14.20	11.30	27.61	39.02	33.6	64.07	3.61	3.92
96	LaSalle	39	7.56	8.08	12.76	29.02	42.58	40.6	58.92	3.63	1.14
97	Lauder	149	6.35	17.80	12.16	28.65	35.04	34.1	57.05	3.25	3.17
98	Lincoln	50	10.64	15.00	10.89	25.89	37.58	32.3	62.19	3.46	2.44
99	Lincoln	51	10.44	8.58	12.91	25.97	42.10	29.9	59.71	3.25	3.10
100	Litchfield	89	7.94	13.84	12.16	24.18	41.88	29.6	65.44	3.55	1.77
101	Litchfield	90	9.22	5.96	14.06	24.68	46.08	31.9	64.81	3.58	3.23
102	Marissa	103	7.78	7.34	13.26	27.52	44.10	30.7	59 43	3.24	3.93
103	Marissa	104	7.15	13.77	12.48	25.39	41.21	27.9	61.07	3.28	3.30
104	Moweaqua	126	8.07	10.78	13.50	23.64	44.01	27.9	60.77	3.27	3.27
105	Moweaqua	127	9.19	10.16	13.34	23.48	43.83	31.2	63.61	3.51	3.80
106	Mt. Olive	62	9.30	4.53	15.25	27.14	43.78	25.5	55.82	3.03	3.86
107	Mt. Olive	63	9.62	14.55	13.12	21.09	41.62	28.8	59.41	3.20	2.73
108	Mt. Pulaski	52	11.98	12.10	10.58	23.06	42.28	24.1	73.82	4.05	.62
109	Murphysboro	31	4.96	4.39	12.16	22.46	56.03	24.4	72.48	3.97	.62
110	Murphysboro	32	6.21	4.72	12 00	22.29	54.78	28.4	60.28	3.25	2.43
111	Mid letown	83	10.04	9.90	14.10	22.79	43.17	30.1	53.36	2.90	3.13
112	Middletown	84	10.37	19.20	11.04	22.08	37.31	26.0	51.47	3.21	3.27
113	Niantic	58	10.38	9.14	14.53	21.94	44.01	27.9	54.58	2.95	3.35
114	Niantic	59	11.01	15.16	12.95	21.56	39.32	30.5	57.32	3.13	1.93
115	Norris	23	11.78	14.18	10.66	22.54	40.84	34.6	56.82	3.23	1.98
116	Norris	24	9.44	19.70	8.83	24.85	37.18	28.3	62.16	3.35	3.00
117	Odin	74	8.52	9.82	13.15	23.96	44.55	30.4	58.86	3.20	3.80
118	Odin	75	6.92	15.95	11.27	24.89	40.97	32.6	64.68	3 62	2.62
119	Oglesby	40	10.28	4.09	14.71	27.32	43.60	31 8	56.12	3.11	4.66
120	Oglesby	41	8.28	17.54	10.29	25.63	38.26	34.8	63.24	3.59	3.20
121	Pana	5	9.00	8.30	12.67	28.75	41.28	36.8	62.86	3.66	2.96
122	Pana	6	8.06	18.66	13.98	29.72	37.44	31.7	54.76	3.02	3.45
123	Pana	7	7.80	8.74	12 05	23.79	39.74	26.2	65.71	3.56	.75
124	Pinckneyville	95	7.54	7.30	17.18	22.03	45.96	26.7	62.72	3.38	1.88
125	Pinckneyville	96	7.26	22.22	11.35	20.01	39.16	26.4	53.20	2.87	3.10
126	Riverton	122	3.38	16.46	11.34	25.62	43.20	29.7	61.40	3.32	4.10
127	Sandoval	76	5.51	11 94	12.70	24.11	45.74	28.3	63.80	3.45	2.60
128	Sherrard	87	9.60	8.82	10.09	29.27	42.22	34.7	64.79	3.68	3.02
129	Sherrard	88	7.84	18.39	11.79	24.93	37.05	31.7	54.20	3.00	4.78
130	Sparta	97	7.44	8.64	14.41	23.23	46.28	27.4	63.69	3.42	2.40
131	Sparta	98	7.09	8.93	14.53	22.22	47.23	24.5	62.57	3.43	3.45
132	Springfield	123	4.74	11.34	12.63	24.01	47.28	27.1	64.90	3.49	2.90
133	Springfield	124	11.32	12.96	11.79	25.29	38.64	32.1	56.87	3.16	3.90
134	Springfield	125	11.56	12.16	10.77	23.77	41.74	28.4	58.29	3.14	4.08
135	Streator	42	8.47	11.98	9.88	26.15	43.52	29.8	62.00	3.37	4.30
136	Streator	43	7.96	6.35	9.98	29.86	45.85	33.1	68.50	3.83	3 38
137	Streator	44	6.88	9.57	10 43	28.31	44.81	32.0	65.82	3.64	3.66
138	Streator	45	5.52	5.40	11.36	30.74	46.98	33.5	70.67	3.98	3.07

Table XV—Concluded.

	Town.	No. table	Moisture	Ash	Inert volatile	Combustible volatile	Fixed carbon	Ratio	Total carbon	Available hydrogen	Sulphur
139	Tilden	99	7.17	13.15	11.06	23.64	44.98	27.6	62.12	3.37	3.13
140	Tilden	100	8.68	7.73	12.26	24.80	46.53	28.2	64.76	3.50	3.07
141	Trenton,	11	8.76	20.19	11.43	16.57	43.05	22.2	55.28	3.02	1.32
142	Trenton	12	9.47	15.28	11.88	18.10	45.27	23.3	58.99	3.26	1.12
143	Virden	64	10.27	8.08	16.12	22.13	43.40	28.5	60.75	3.28	1.50
144	Virden	65	10.21	9.87	14.21	23.39	42.32	29.1	59.67	3.24	2.80
145	Wenona	77	10.94	2.32	12.20	24.39	50.15	28.4	69.98	3.77	.79
146	Wenona	78	10.31	13.14	9.51	23.98	43.06	29.5	61.06	3.31	2.67
147	S. Westville	137	11.20	5.82	13.91	21.95	47.12	27.2	64.74	3.50	.85
148	S. Westville	138	11.06	7.30	12.06	23.28	46.30	29.0	65,21	3.53	.84
149	S. Wilmington	27	7.80	29.35	10.00	18.84	34.01	26.7	46.35	2.52	3.98
150	S. Wilmington	28	11.44	5.36	10.54	26.55	46.11	31.0	66.89	3.67	2.10

TESTS WITH ILLINOIS COALS UNDER STEAM BOILERS.

(By L. P. Breckenridge.)

The following is a brief review of a number of boiler trials with various Illinois coals made by the Mechanical Engineering department of the University of Illinois. The tests were made at the different power plants of the University and neighboring towns. The conditions under which the tests were made were usually those ordinarily obtaining at the different plants, and it is fair to assume that they represent average conditions throughout the State. The tests were made by students of the department, sometimes for instructional purposes and sometimes for investigational purposes as thesis work.

The coals used were for the most part those in common use at the plants, although in some cases special coals were used to obtain their evaporative efficiency under a boiler. There were thirty-five different coals tested, representing fourteen counties of the State.

The following types of boilers were used in these trials:

(1)	Stirling water-tube boilers	2 settings.
(2)	National water-tube boiler	2 "
(3)	Heine water-tube boiler	1 "
(4)	Babcock and Wilcox water-tube boiler	8 "
(5)	Horizontal tubular boiler	11 ".

The settings of these boilers included the following:

One Murphy smokeless furnace.
One Roney automatic stoker.
Two Green chain grate stokers.
One Babcock and Wilcox chain grate stoker.
One Brightman stoker.

All other tests were made with hand-fired furnaces and plain or rocking grates.

The results of these tests are shown in Tables I and II, the tests being arranged according to the counties in which the coals were mined. Table I gives the conditions under which the tests were made. Table II gives some of the more important results. The headings need no special explanation. Where a series of tests was made with the same coal under like conditions, the average of the series is reported together with the number of tests in the series. Where assumptions were made, they have been indicated in the tables.

A more detailed report of these tests may be found in Bulletin No. 7 of the Engineering Experiment Station of the University of Illinois, which also contains the chemical analysis and heating values of Illinois coals.

TABLE I.

BOILER TESTS OF ILLINOIS COALS MADE BY THE MECHANICAL ENGINEERING DEPARTMENT, UNIVERSITY OF ILLINOIS, 1894-1905.

Number.	DESCRIPTION OF COALS.			TYPE OF BOILER AND GRATE.	LOCATION OF BOILER.	DATE OF TRIAL.	Duration of trial.	Grate surface.	Water heating surface.	Steam pressure, gauge.	Force of draft between damper and boiler.	Temperature of feed water.	Temperature of escaping flue gases.
	COUNTY.	TOWN.	COMMERCIAL SIZE.				Hours.	Sq. ft.	Sq. ft.	Lbs. per sq. in.	Inches water.	° Fahr.	° Fahr.
					A. S. M. E. Code No.	1	2	3	7	11	12	20	21
1	Christian	Pana	Slack	B. & W. Nos. 1 and 2, plain grate.	Urbana & Cham. elec. lt. plt.	June, 1894	10.12	52.1	2,340	90.2	.220	59.1	498
2	Christian	do	Pea	do	do	June, 1894	10.00	51.0	2,264	91.3	.220	60.9	484
3	Christian	do	Screenings	do	do	June, 1894	10.00	51.0	2,264	95.9	.200	60.0	464
4	Christian	do	Lump and slack.	do	do	June, 1894	10.18	51.0	2,264	95.0	.325	60.7	529
5	Coles	Paradise	Lump	Hor. tub. No. 2, plain grate	Univ. of Ill. M. E. lab	Feb., 1897	8.00	18.7	533	82.1	.405	47.5	549
6	Gallatin	Junction	Pea	Nat. W. T. No. 4, Murphy furn.	Univ. of Ill. cent. heat. plant.	Mar., 1899	7.25	60.7	2,579	108.1	.580	49.1	481
7	Macon	Niantic	Nut	B. & W. No. 5, plain grate	do	Jan., 1895	10.00	51.0	2,450	59.5	.300	49.6	485
8	Macoupin	Mt. Olive	Lump	Hor. tub. No. 2, plain grate	Univ. of Ill. M. E. lab	Feb., 1897	8.00	18.7	533	75.8	.470	47.0	567
9	Madison	Glen Carbon	do	B. & W. No. 2, chain grate	Univ. of Ill. cent. heat. plant.	May, 1901	8.00	28.0	1,486	108.4	.600	60.0	571
10	Marion	Odin	do	Hor. tub. No. 1, plain grate	Univ. of Ill. M. E. lab	April, 1894	7.74	18.7	533	70.3	.262	56.3	489
11	Marion	do	do	Hor. tub. No. 2, plain grate	do	April, 1895	10.10	18.7	533	59.0	.200	53.7	680
12	Marion	do	Pea	do	do	June, 1896	9.50	18.7	533	67.8	.163	61.1	508
13	Marion	do	do	Hor. tub. No. 1, plain grate	do	Oct., 1896	8.00	16.6	547	73.0	.200	59.6	494
14	Marion	do	do	Hor. tub. Nos. 3 and 4, plain grate	Urbana & Cham. water wks.	Jan., 1897	8.00	45.0	2,260	70.8	.394	128.0	359
15	Marion	do	Lump	Hor. tub. No. 4, rocking grate	Univ. of Ill. cent. heat. plant.	Mar., 1895	9.38	30.0	1,010	69.4	.219	52.2	560
16	Marion	do	do	B. & W. No. 5, plain grate	do	Jan., 1895	8.71	51.0	2,450	67.8	.330	50.9	478
17	Marion	do	Pea	do	do	Mar., 1899	8.00	51.0	2,450	103.7	.600	49.7	518
18	Marion	do	Lump	Stirling No. 3, plain grate	do	Nov., 1896	7.85	13.5	525	82.0	.250	218.0	544
19	Marion	do	do	B. & W. No. 2, plain grate	Urb'a & Cham. E. L. & P. Co.	June, 1894	10.00	51.0	2,264	98.5	.210	59.5	482
20	Marion	do	Slack	do	do	Dec., 1896	8.00	51.0	2,264	106.4	.730	45.0	462
21	Marion	do	Duff	Stirling Nos. 7 and 8, plain grate.	do	Mar., 1905	23.60	50.9	2,587	110.6	.650	178.5	591

22	Marion	do	Pea	Nat. W. T. No. 4, Murphy furnace	Univ. of Ill. cent. heat. plant.	Jan.,	1899	8.00	60.7	2,579	84.7	.515	53.0	502
23	McLean	Bloomington	Lump	Hor. tub. No. 2, plain grate	Univ of Ill. M. E. lab.	Feb.,	1895	10.76	18.7	533	65.6	.243	52.2	578
24	McLean	do	do	B. & W. No. 5, plain grate	Univ. of Ill. cent. heat. plant	Dec.,	1894	6.00	51.0	2,450	53.6	.300	53.6	....
25	McLean	Colfax	do	B. & W. No. 1, plain grate	do	May,	1902	8.00	35.0	1,486	106.3	.500	70.5	....
26	Menard	Athens	do	Hor. tub. No. 2, plain grate	Univ. of Ill. M. E. lab.	Mar.,	1897	7.83	18.7	533	77.5	.190	50.6	523
27	Perry	DuQuoin	do	Hor. tub. No. 1, lain grate	do	Oct.,	1895	8.00	16.6	547	63.1	.236	63.6	528
28	Perry	do	do	Hor. tnb No. 2, plain grate	do	June,	1896	9.25	18.7	533	69.0	.180	61.6	503
29	Perry	do	Slack	Hor. tub., plain grate	Twin City Ice & C. Stor. Co.	April,	1898	8.00	22.5	870	93.0	.320	177.7	535
30	Perry	do	Lump	Hor. tub. No. 4, rocking grate	Univ. of Ill. cent. heat. plant.	Feb.,	1895	9.00	30.0	1,010	65.6	.257	48.4	519
31	Perry	do	do	B. & W. No. 5, plain grate	do	Feb.,	1895	9.50	51.0	2,450	68.3	.303	49.8	515
32	Perry	do	Pea	B. & W. No. 2, plain grate	Urb'a & Cham. E. L. & P. Co.	Mar.,	1901	12.00	51.0	2,264	108.5	.700	69.2	420
33	Sangamon	Barclay	do	Hor. tub., rocking grate	Decatur, Ill., water works	April,	1898	7.50	25.0	.....	88.8	.300	100.1	403
34	Sangamon	Dawson	do	B. & W. Nos. 5 and 6, plain grate	Univ. of Ill. cent. heat. plant.	Mar.,	1899	8.00	51.0	2,450	105.8	.600	53.4	539
35	Sangamon	do	do	Nat. W. T. No. 4, Murphy furnace	do	Mar.,	1899	8.00	60.7	2,579	104.3	.540	52.1	503
36	Sangamon	Divernon	Lump	B. & W. No. 2, chain grate	do	May,	1901	8.00	28.0	1,486	102.3	.600	60.6	512
37	Sangamon	Lowder	Slack	do	do	April,	1904	8.00	28.0	1,486	119.0	.325	78.5	453
38	Sangamon	Ridgely	Pea	Nat. W. T. No. 4, Murphy furnace	do	Feb.,	1899	8.00	60.7	2,579	106.5	.550	49.5	495
39	Sangamon	Riverton	do	do	do	Mar.,	1899	8.00	60.7	2,579	110.8	.420	48.3	462
40	Sangamon	do	do	B. & W. Nos. 5 and 6, Roney st'r	do	Jan.,	1904	24.00	51.0	2,353	119.4	.270	60.6	559
41	Sangamon	do	do	B. & W. No. 2, chain grate	do	Dec.,	1903	8.00	28.0	1,486	113.7	.700	63.7	530
42	Sangamon	do	do	do	do	Jan.,	1904	8.00	28.0	1,486	113.7	.670	63.2	535
43	Sangamon	do	do	do	do	Feb.,	1904	8.00	28.0	1,486	115.0	.630	72.0	435
44	Sangamon	do	do	do	do	Mar.,	1904	8.00	28.0	1,486	118.7	.580	73.5	441
45	Sangamon	do	do	do	do	Jan.,	1904	8.00	28.0	1,486	114.4	.170	65.2	464
46	Sangamon		Lump	Hor. tub. No. 2, plain grate	Univ. of Illinois, M. E. lab.	Feb.,	1897	8.51	18.7	533	75.2	.306	48.0	519
47	Sangamon			B. & W. No. 2, chain grate	Univ. of Ill., cent. heat. plant	April,	1904	8.00	28.0	1,486	121.6	.145	72.3	492
48	Sangamon			National W. T. No. 4, chain g'te	do	Jan.,	1905	9.77	59.0	2,513	117.8	.360	79.8	635
49	Sangamon			do	do	April,	1905	10.02	55.8	2,513	122.9	.370	73.6	584
50	Sangamon	Springfield	Pea	B. & W. No. 1, plain grate	do	April,	1901	8.19	35.0	1,486	104.9	.620	63.5	462
51	Sangamon	do	do	B. & W. No. 2, chain grate	do	April,	1901	8.00	35.0	1,486	102.8	.640	57.4	519
52	Sangamon	do	do	B. & W. No. 6, Roney stoker	do	Nov.,	1905	10.00	51.0	2,353	128.4	.290	61.5	608
53	Shelby	Moweaqua	Lump	B. & W. No. 5, plain grate	do	Jan.,	1895	10.00	51.0	2,450	55.0	.300	51.5	489
54	Vermilion	Catlin	Screenings	Murray H. T. Nos 1, 2, 3, rk'g gr'te	Urbana Lt., Ht. & Power Co	Mar.,	1905	47.66	33.0	1,456	98.9	.640	130.6	393
55	Vermilion	Fairmount	do	B. & W. No. 2, plain grate	Urbana & Cham. E. L. & P. Co	Dec.,	1896	8.00	51.0	2,264	108.2	.740	54.0	487
56	Vermilion	Muncie	Slack	Hor. tub. Nos. 2 and 3, plain gr'te	Urbana & Cham. water works	Nov.,	1895	10.00	22.5	1,060	74.8	.430	140.0	301
57	Vermilion	Oakwood	Lump	Stirling Nos. 7 and 8, plain grate	Urbana & Cham. E. L. & P. Co	Mar.,	1905	24.00	50.9	2,587	112.3	.790	182.8	634
58	Vermilion	do	Screenings	do	do	April,	1905	10.80	50.9	2,587	110.7	.790	200.0	616
59	Vermilion	do	do	B. & W., plain grate	do	April,	1905	10.33	64.0	2,860	102.0	.330	178.0	565
60	Vermilion	do	do	Heine, chain grate	do	May,	1905	8.03	72.0	3,160	111.9	.710	63.5	592
61	Vermilion	do	Pea	B. & W. No. 6, Roney stoker	Univ. of Ill., cent. heat. plant	Nov.,	1905	10.00	51.0	2,353	133.2	.226	98.3	593
62	Williamson	Carterville	W. pea and Duff	do	do	Nov.,	1905	10.00	51.0	2,353	132.9	.235	61.0	609
63	Williamson	Herrin	New Ky. pea	B. & W. No. 2, chain grate	do	April,	1904	9.33	28.0	1,486	117.0	.490	65.0	529
64	Williamson	do	N. (Ky.) W. sc'n	do	do	April,	1904	20.00	28.0	1,486	120.1	.540	62.0	534
65	Williamson	do	do	B. & W. Nos. 5 and 6, Roney st'r.	do	Feb.,	1904	12.00	51.0	2,353	117.9	.166	57.8	656

TABLE II.

BOILER TESTS WITH ILLINOIS COALS MADE BY THE MECHANICAL ENGINEERING DEPARTMENT, UNIVERSITY OF ILLINOIS, 1894-1905.

Number.	Description of Coals. County.	Town.	Commercial Size.	Type of Boiler and Grate.	Number of tests averaged.	Dry coal per square foot of grate surface per hour.	Horsepower developed by boiler.	Percentage of rated horse-power developed.	Equivalent Evaporation from and at 212 Degrees Fahrenheit. Per square foot of water-heating surface per hour.	Per pound of dry coal.	Per pound of combustible.	B. T. U. per pound of dry coal.	Efficiency of boiler, including grate.	
						Lbs.		Per cent.	Lbs.	Lbs.	Lbs.		Per cent.	
				A. S. M. E. Code No.		49	65	67	64	70	71	50	73	
1	Christian	Pana	Slack	B. & W. Nos. 1 and 2, plain grate	4	15.10	108.5	51.7	1.60	4.90	6.38	......	......	§
2	Christian	do	Pea	do	1	13.80	110.8	52.8	1.69	5.44	6.63	......	......	§
3	Christian	do	Screenings	do	1	14.90	114.9	54.7	1.75	5.21	6.18	......	......	§
4	Christian	do	Lump and slack	do	1	20.40	196.4	93.5	2.99	6.50	7.44	......	......	§
5	Coles	Paradise	Lump	Hor. tub. No. 2, plain grate	2	13.56	52.0	130.0	3.37	7.05	7.78	11,430	59.6	
6	Gallatin	Junction	Pea	National W. T. No. 4, Murphy furnace	4	18.43	206.3	82.5	2.76	6.36	7.09	......	......	§
7	Macon	Niantic	Nut	B. & W. No. 5, plain grate	1	18.74	135.4	61.5	1.19	4.89	5.95	11,203	42.2	*
8	Macoupin	Mt. Olive	Lump	Hor. tub. No. 2, plain grate	2	13.79	52.1	130.2	3.38	6.96	7.53	......	......	
9	Madison	Glen Carbon	do	B. & W. No. 2, chain grate	3	32.40	135.1	90.1	3.14	5.15	7.17	12,552	39.7	
10	Marion	Odin	do	Hor. tub. No. 1, plain grate	5	10.38	36.6	91.5	2.37	6.48	7.73	......	......	
11	Marion	do	do	Hor. tub. No. 2, plain grate	5	13.63	45.9	114.7	2.97	6.19	7.44	12,110	49.4	*
12	Marion	do	Pea	do	3	8.41	24.6	61.5	1.59	5.38	6.25	11,559	44.9	*
13	Marion	do	do	Hor. tub. No. 1, plain grate	1	11.99	35.5	88.7	2.24	6.13	7.32	11,070	53.5	
14	Marion	do	do	Hor. tub. Nos. 3 and 4, plain grate	3	10.31	84.6	47.0	1.29	6.29	7.49	......	......	
15	Marion	do	Lump	Hor. tub. No. 4, rocking grate	2	22.49	135.0	135.0	4.61	6.91	7.87	......	......	*
16	Marion	do	do	B. & W. No. 5, plain grate	5	20.20	176.4	80.2	2.48	5.91	7.00	12,665	45.1	
17	Marion	do	Pea	do	1	27.10	555.7	126.3	3.91	6.92	8.82	......	......	
18	Marion	do	Lump	Stirling No. 3, plain grate	7	19.91	51.2	85.3	3.37	6.57	7.63	11,633	54.5	

19	Marion	do	do	B. & W. No. 2, plain grate	1	15 20	129.1	61.5	1.97	5.74	6.51	......	......	§
20	Marion	do	Slack	do	1	23.51	205.8	98.0	3 14	5.92	6.83	12,13	7.1	
21	Marion	do	Duff	Stirling Nos. 7 and 8, plain grate	1	20.78	382.6	73.6	2.55	6.24	8.11	11,185	53.8	
22	Marion	do	Pea	National W. T. No. 4, Murphy furnace	2	21.04	216.9	86.8	2.90	5.86	7.13	......	......	§
23	McLean	Bloomington	Lump	Hor. tub. No. 2, plain grate	10	11,34	40.7	101.7	2.64	6.64	8.01	......	......	*
24	McLean	do	do	B. & W. No. 5, plain grate	1	24.76	194.2	88.3	2.73	5.30	6.26	......	......	*
25	McLean	Colfax	do	B. & W. No. 1, plain grate	2	22.70	116.3	77.5	2.70	5.06	6.64	12,025	40.6	
26	Menard	Athens	do	Hor. tub. No. 2, plain grate	2	11.63	41.0	102.5	2.66	6.49	7.09	13,824	45.3	
27	Perry	DuQuoin	do	Hor. tub. No. 1, plain grate	4	10.66	28.6	71.5	1.80	5.54	6.49	12,174	43.9	*†
28	Perry	do	do	Hor. tub. No. 2, plain grate	2	7.37	24.6	61.5	1.59	6.15	6.85	11,980	49.6	
29	Perry	do	Slack	Hor. tub., plain grate	1	15.96	73.9	123.2	2.93	7.10	8.60	11,761	58.3	
30	Perry	do	Lump	Hor. tub. No. 4, rocking grate	1	18.24	117.0	117.0	4.00	7.38	8.30	12,174	58.5	*
31	Perry	do	do	B. & W. No. 5, plain grate	2	19.59	190.3	86.5	2.68	6.57	7.52	......	......	*
32	Perry	do	Pea	B. & W. No. 2, plain grate	2	16.06	118.5	56.4	1.81	5.00	5.87	......	......	
33	Sangamon	Barclay	do	Hor. tub., rocking grate	2	24.31	118.7	......	......	6.74	7.75	......	......	
34	Sangamon	Dawson	do	B. & W. Nos. 5 and 6, plain grate	1	29.00	543.7	123.6	3.83	6.34	7.64	......	......	
35	Sangamon	do	do	National W. T. No. 4, Murphy furnace	3	15.95	152.2	60.9	2.04	5.42	6.21	......	......	
36	Sangamon	Divernon	Lump	B. &. W. No. 2, chain grate	3	28.60	125.9	83.9	2.92	5.42	6.98	11,239	46.6	
37	Sangamon	Lowder	Slack	do	2	22.40	103.5	69.0	2.41	5.69	7.06	11,700	47.0	
38	Sangamon	Ridgely	Pea	National W. T. No. 4, Murphy furnace	6	18.00	179.7	71.9	2.40	5.68	6.33	......	......	
39	Sangamon	Riverton	do	National W. T. No. 4, Murphy furnace	3	19.21	205.2	82.1	2.75	6.07	6.76	......	......	
40	Sangamon	do	do	B. & W. No. 5 and 6, Roney Stoker	1	24.30	463.1	105.3	3.39	6.43	8.12	9,975	62.2	
41	Sangamon	do	do	B. & W. No. 2, chain grate	4	34.30	165.7	110.4	3.85	5.96	7.39	11,152	51.7	
42	Sangamon	do	do	do	3	34.90	185.1	123.4	4.30	6.53	7.95	11,152	56.7	
43	Sangamon	do	do	do	4	17.90	89.1	59.4	2.07	6.15	8 26	11.152	53.3	
44	Sangamon	do	do	do	4	19.90	114.9	76.6	2.67	7.11	8.93	11,152	62.2	
45	Sangamon	do	do	do		20.50	91.4	60.9	2.12	5.49	6.23	11,287	47.0	
46	Sangamon		Lump	Hor. tub. No. 2, plain grate	4	13.00	48.3	120.7	3.13	6.84	7.83	11,980	55.1	
47	Sangamon		Pea	B. & W. No. 2, chain grate	2	21.84	114.6	76.4	2.66	6.47	7.44	11,930	52.4	
48	Sangamon		do	National W. T. No. 4, chain grate	4	30.52	335.8	134.3	4.61	6.43	8.21	12,162	51.5	
49	Sangamon		do	do		30.73	331.2	132.5	4.55	6.67	8.10	11,537	55.9	
50	Sangamon	Springfield	do	B. & W. No. 1, plain grate	2	25.70	111.3	74.2	2.58	4.27	5.18	......	......	§
51	Sangamon	do	do	B. & W. No. 2, chain grate	2	28.20	176.3	117.5	4 09	6.16	7.75	......	......	§
52	Sangamon	do	do	B. & W. No. 6, Roney Stoker	2	24.37	238.4	101.4	3.44	6.51	7.79	12,591	49.9	
53	Shelby	Moweaqua	Lump	B. & W. No. 5, plain grate		20.78	164 4	74.7	2.32	5.35	6.27	13,026	39.7	*
54	Vermilion	Catlin	Screenings	Murray hor. tub. No. 1, 2, 3, rocking grate		11.27	100.1	66.7	1.58	6.19	8.15	12,369	48.3	
55	Vermilion	Fairmount	do	B. & W. No. 2, plain grate		30.67	230.1	109.6	3.51	5.08	5.95	12,413	39.5	
56	Vermilion	Munice	Slack	Hor. tub. No. 2 and 3, plain grate		13.62	107.9	63.5	1.76	6.07	7.50	......	......	†
57	Vermilion	Oakwood	Lump	Stirling No. 7 and 8, plain grate		25.42	497.6	95.7	3.32	6.63	8.07	12,503	51.0	
58	Vermilion	do	Screenings	do		25.09	507.4	97.6	3.38	6.85	8.39	11,427	57.9	
59	Vermilion	do	do	B. & W. plain grate		17.91	166.9	64.2	2.01	5.02	6.59	10,299	47.1	
60	Vermilion	do	do	Heine chain grate		23.94	382.7	109.3	4.18	7.66	9.64	11,067	66.8	
61	Vermilion	do	Pea	B. & W. No. 6, Roney Stoker	2	22.40	230.9	98.3	3.39	7.15	8.58	13,251	52.1	
62	Williamson	Carterville	W. pea and duff	do	3	19.96	240.2	102 2	3.52	8.14	8.89	13,408	58.6	
63	Williamson	Herrin	New Ky. Pea	B. & W. No. 2, chain grate	3	32.93	196.0	130.7	4.55	7.34	8.74	12,769	55.5	
64	Williamson	do	N.Ky.W.Screen	do	1	34.60	210.3	140.2	4.88	7.50	8.89	13,156	55.0	
65	Williamson	do	do	B. & W. No. 5 and 6, Roney Stoker	1	26.55	620.7	132.1	4.55	7.75	9.21	12,364	60.5	

* Steam assumed dry. † Coal assumed dry. § Moisture obtained by drying coal above boiler.

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